VOL. 43
NO. 10

CHEMICAL & METALLURGICAL ENGINEERING

OCTOBER, 1936

SEVENTH MATERIALS OF CONSTRUCTION NUMBER

Price of this issue one dollar per copy.

Published monthly, price 35 cents a copy. Subscription rates—United States, Canada, Mexico, and Central and South American countries, $3.00 a year. All other countries, $5.00 a year or 20 shillings. Entered as second-class matter September 2, 1936, at the Post Office at Albany, N. Y., under the Act of March 3, 1879. Printed in U. S. A. Member A.B.C. Member A.B.P.

McGRAW-HILL PUBLISHING COMPANY, INC.

Publication office, 99-129 N. Broadwway, Albany, N. Y., Editorial and executive offices, 330 West 42nd St., New York, N. Y. Cable address, McGrawhill, N. Y.

Branch Offices: 520 North Michigan Ave., Chicago; San Francisco; Aldwych House, Aldwych, London, W. C. 2; Washington; Philadelphia; Cleveland; Detroit; St. Louis; Boston; Atlanta.

Volume 43
Number 10

CHEMICAL
& METALLURGICAL
ENGINEERING

Established 1902

McGRAW-HILL PUBLISHING COMPANY, INC.

S. D. KIRKPATRICK, Editor

OCTOBER
1936

Your Materials Handbook

IN THE PLANT MUSEUM at Oppau is a unique exhibit that tells a dramatic story. It is the original laboratory apparatus and semi-works equipment in which the late Professor Fritz Haber made the first synthetic ammonia. There is shown, step by step, the slow progress he was able to make *only* after he had developed suitable materials of construction to withstand the high pressures and temperatures involved. Some of the first retorts were so badly corroded that one wonders how explosions were avoided. Gradually, however, the large forgings of alloy steel were perfected and in them were placed the chrome-nickel liners—thus meeting the stringent requirements for both corrosion resistance and high strength of construction.

These problems faced by Haber and Bosch in Germany twenty-five years ago are still being met and solved by chemical engineers all over the world. Tremendous progress has been made recently by the metallurgists and materials manufacturers but the end is not yet in sight. Already, intrepid researchers are clamoring for new metal that will stand a hundred or even two hundred thousand pounds of pressure and temperatures up to a thousand degrees Fahrenheit. Men in laboratories are playing with new reactions, using extremely corrosive chemicals subjected to severest physical conditions. Plant men are dreaming and scheming of larger and more efficient units that must await the development of new metals and alloys. All are part of a great advance in technology that is stimulating alike to the producer and user of corrosion, heat and abrasion resistant materials of construction.

In the past dozen years *Chem. & Met.* has devoted six of its special theme issues to the task of summarizing, correlating and interpreting the advances made in the development and better use of modern materials of construction. In this seventh of the series it has been our aim to present, in convenient handbook form, the vital facts and figures that should be most useful in solving practically any corrosion problem to be met in the process industries. Trends and new developments of the past two years are summarized in a few brief paragraphs for each of the twenty-five divisions or classifications of materials. Corrosion data from many different sources are presented in graphs or tables. Chemical, physical and mechanical properties and essential commercial information are concisely tabulated and, finally, the whole is inventoried in a reference index on pages 563 and 564 of this issue.

This, in truth, is a chemical engineer's handbook of materials, more up to date and comprehensive than any other source. It is presented in a form that we hope will prove useful in solving the practical problems on which the process industries must depend for their future progress and profits.

Aluminum and Alloys

ALUMINUM alloys cover a wide range of composition and of physical properties. They vary from high-purity aluminum, containing 99.6 per cent of the metal, through a series of alloys with greater or lesser proportions of various alloying elements. These alloys may, by appropriate heat treatment, be given physical characteristics covering a wide range.

The metal may be obtained in either the wrought or cast form of almost any shape desired, and may be bolted, soldered, welded, or screwed together for fabricating equipment. Most of the other metals used in the construction of chemical equipment are from two and a half to three and a quarter times as heavy as aluminum. Much work is being done on the development of suitable solders for aluminum and aluminum alloys, as shown by the large numbers of patents issued on the subject. Zinc base hand solders and mixtures of zinc, aluminum and tin are finding considerable popularity for this purpose.

Since pure aluminum is difficult to cast, it is generally worked into shape by drawing, hammering, forging, or extrusion. The metal and its alloys are strengthened by cold working and may be obtained not only in annealed, but also in various degrees of temper. If the equipment is intended for service at high temperatures the work should begin with only half-hardened metal; the greater internal stress in the more highly-worked full-hard material lowers the annealing or softening temperature so that after some time at, for example, 390 deg. F., the half-hard sheet remains stronger than the full-hard material. A new alloy containing a small amount of magnesium may be strengthened by heat-treatment. The metal and its alloys are suitable for low-temperature service, for their ductility increases as the temperature drops. They do not show any tendency to develop brittleness at low temperatures.

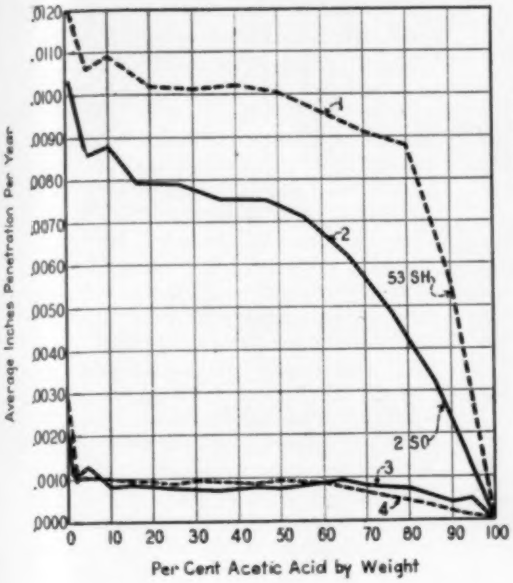
The chemical engineer generally uses the two grades—99.6 per cent or 99.2 per cent aluminum. The latter is satisfactory for many purposes, but for certain chemical operations the higher quality metal is required. Interesting applications for the metal are the gooseneck and receiver shown here. This equipment is made use of in the production of stearic acid.

Principal Fields of Application

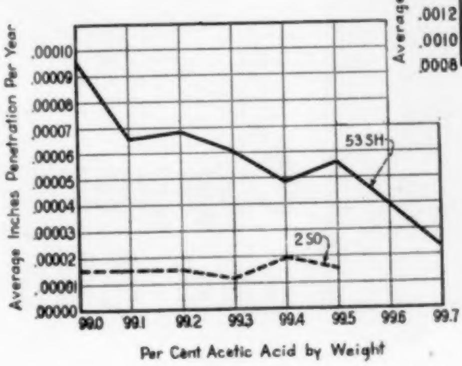
Alloy	Principal Application	Design Stresses: No Welding Lb., sq.in.	Design Stresses: Welded Lb., sq.in.	Temperature Factors 300° F.	Temperature Factors 500° F
99.6% ½H..	Where chemical conditions require maximum corrosion resistance	4500	3000	.60	.30
99.6% H..		6500	3000	.60	.25
2S ½H..	Widely used when corrosion resistance is of greater importance than strength	5000	3000	.60	.30
2S H..		7000	3000	.60	.25
3S ½H..	Used when combination of good corrosion resistance and fairly high physical properties is desired	6000	4000	.60	.30
3S H..		8000	4000	.60	.25
52S ¼H..	Used when excellent corrosion resistance must be combined with high strength in an alloy which is not heat treated. Usually used in form of sheet	9000	5000–6000	.90	.55
52S ½H..		11000	5000–6000	.85	.40
52S ¾H..		12000	5000–6000	.80	.30
53SW......	Especially for shipping containers. Has excellent corrosion resistance and high strength in heat treated conditions. Widely used for forgings, tubing and shapes under severely corrosive conditions	7000	4500	.70	.15
53S-T......		13000	4500	.70	.15
17S-T......	Used when corrosive conditions are not severe and high strength is required	15000	Should not be welded	.60	.15
43..........	Casting alloy. Used when good corrosion resistance is required and high strength is not needed	5000	....	.70	.40
356.........	Heat treated casting alloy. Used when good corrosion resistance must be combined with high strength	8000	....	.85	.30
214.........	Has excellent corrosion resistance. Machines and polishes well and has good physical properties. Widely used under corrosive conditions except when contact with acids is involved	6000	....	.90	.50
195.........	Used when maximum strength is required in heat treated casting which will not be exposed to severely corrosive conditions	9000	....	.80	.30

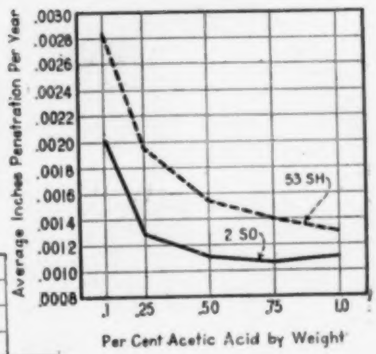
Which Alloy to Use

Process or Product	Equipment	Preferred Alloy
Fatty acids	Condenser	2S or 3S
	Slab pans	2S or 3S
	Tanks	2S or 3S
Naval stores	Stills	2S or 3S
	Condensers	2S or 3S
	Filters	2S or 3S
Tartaric Acid	Crystallizers	High purity
	Tanks	High purity
Rayon	Spinning spools	99.6%
	Spinning buckets	53S-T
	Ducts	99.6%
Citric acid	Pans	High purity
	Tanks	High purity
Gelatine	Cooking vats	52S
	Evaporators	2S or 3S
	Tanks	2S or 3S
	Drying screens	2S
Varnish	Kettles	52S
Dyeing	Pressure dyers	99.6%
Formalaehyde	Tanks	3S
Acetic acid	Tanks	3S
Nitric acid	Tanks	3S
Edible oils	Deodorizers	2S
	Bleaching tanks	3S
	Storage tanks	3S
Ammonium nitrate	Concentrators	3S
	Crystallisers	3S
Hydrogen peroxide	Tanks	99.6%
Synthetic resins	Stills	99.6%
	Condensers	2S or 3S
	Tanks	2S or 3S
Cellulose acetate	Acid tanks	2S or 3S
	Precipitating tanks	3S
	Extractors	53S-T
	Driers	3S



Left—Corrosion of aluminum. Curves 1 and 2 drawn from immersion at 122 deg. F. for 48 hr. Curves 3 and 4 drawn from immersion at room temperature for 60 days. 53SH is an alloy, full-hard temper; and 2SO is commercially pure metal, annealed.





Corrosion of aluminum after 60 days immersion at room temperature. (Diagrams from Frary, Trans. of A.I.Ch.E.)

Aluminum Metals vs. Salt Solutions

	Mg. per sq. dm. per day	
	Aluminum	Duralumin
Ammonium chloride — 5%	4	4
Magnesium chloride — 1%	0.7	0.7
Sodium sulphate — 10%	*	*
Magnesium sulphate — 5%	0.3	0.3

* No determinable weight loss.

Aluminum vs. Ammonium Salts

	Mg. per sq. dm. per day	
Ammonium carbonate	<1	<1
Ammonium chloride	1.5—<1	5—1
Ammonium sulphate	<1	1.1—<1
Ammonium nitrate	0	0

(McKay and Worthington, Corrosion Resistance of Metals and Alloys.)

Physical Properties of Aluminum and Aluminum Alloys

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10^{6}	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.^{2}	Yield Point, 1,000 Lb. per in.^{2}	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.^{2} x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
2	Aluminum 99.6%														
3	Aluminum 2S	2.71			0.53	All	13-24	4-21	40		10.5	23-44	Good	Yes	DD, F, R, W
4	Aluminum 3S	2.73			0.40	All	16-29	5-25	10-30		10.5	28-55	Good	Yes	DD, F, R, W
5	Aluminum 17S-T	2.79			0.27	All	55	30	16			90			
6	Aluminum 43	2.66				All	19	9	4			40			
7	Aluminum 52S	2.67			0.32	All	29-41	14-36	7-8			45-85			
8	Aluminum 53S-T	2.69			0.36	All	36	30	16			75			
9	Aluminum 195	2.77				All	31-40	16-27	2-8			65-95			
10	Aluminum 214	2.66				All	25	12	9			50			
11	Aluminum 356	2.66				All	25-32	16-22	2-6			55-70			

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

Composition, Forms Available and Names of Aluminum Alloys

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
1	Aluminum, high purity	Aluminum Co. of Amer., Pittsburgh, Pa.	Al	
2	Aluminum 99.6%	Aluminum Co. of Amer., Pittsburgh, Pa.	Al	
3	Aluminum 2S	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; no alloying elements; 1% max. natural impurities	P, S, W, B, T, CR
4	Aluminum 3S	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Mn, 1.25	P, S, W, B, T
5	Aluminum 17S-T	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Cu, 4.0; Mn, 0.5; Mg, 0.5	CR, P, S, T, W, B
6	Aluminum 43	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Si, 5.0	C
7	Aluminum 52S	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Mg, 2.5; Cr, 0.25	P, S, W, B, T
8	Aluminum 53S-T	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Mg, 1.25; Cr, 0.25; Mn, 0.70	P, S, W, B, T
9	Aluminum 195	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Cu, 4.0	C
10	Aluminum 214	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Mg, 3.75	C
11	Aluminum 356	Aluminum Co. of Amer., Pittsburgh, Pa.	Al; Mg, 0.30; Si, 7.0	C

** Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.

Copper and Alloys

ALMOST ANY PLANT one might visit in the process industries would likely be a user of copper, brass, bronze or some other copper alloy. The number and variety of these applications is almost legion. One of these products of highest quality is known as deoxidized copper which contains a minimum of 99.9 per cent of the metal. Tubes of deoxidized copper are extensively used in chemical engineering equipment, such as heaters, coolers and evaporators. A new alloy that might be encountered is a form of copper to which chromium has been added to improve the strength and hardness of the metal. Such copper alloys are especially useful in applications where the drainage of heat away from or the conduction of heat to substances is desired. Another new development is a silver-bearing copper alloy. It has high thermal conductivity and retains the strength imparted by cold working, even to moderately high temperature.

Beryllium has been added to copper to give it a unique property—to make it non-sparking when used to strike a steel or other metallic object. This characteristic, together with its high strength and resistance to wear and corrosion, makes possible the use of copper-beryllium alloys for hammers and blades in grinding mills, pulpers and mixers. Hand tools, such as chisels, hammers, scrapers and wrenches are made of the beryllium alloy for use in explosive atmospheres.

A copper base alloy containing 4 per cent of nickel and a like amount of aluminum is reported to have excellent resistance to the impingement type of corrosive attack met in condenser tubes. Its resistance to sulphur attack results in a considerable number of applications for condenser and heat exchanger tubes in petroleum refineries.

Aluminum bronzes are widely and satisfactorily used for resistance to hot or cold sulphuric acid, as dilute as 5 per cent and as concentrated as 60 deg. B. (77 per cent). This alloy has the additional advantage that to a remarkable degree it retains its tensile strength up to 900 deg. F. Results of tests made at the Massachusetts Institute of Technology in February, 1923, for the American Manganese Bronze Co., are shown in an accompanying chart.

Of especial interest, also, is a group of copper alloys in which there is from 1 to 5 per cent of silicon and 1 to 2 per cent manganese, tin or iron. Their principal value lies in their resistance to hydrochloric acid—an application in which pure copper does not show very favorable results.

In general use in the process industries is a group of alloys varying in composition from 65 to 75 per cent copper, 20 to 30 per cent nickel, and 5 per cent zinc. These alloys are available in all forms and possess a wide range of physical properties. They are extensively used to resist salt and alkaline solutions, dilute sulphuric acid, dilute chlorine bleach solution, and anhydrous ammonia gas or liquid.

Although by no means new, the alloy known as red brass (85 per cent copper and 15 per cent zinc) is rapidly gaining in process uses. In extensive laboratory and service tests reported by D. K. Crampton, before the recent Pittsburgh meeting of the American Chemical Society, red brass has been found to have about the optimum general corrosion resistance of any of the copper alloys suitable for fabrication into pipe or tubes. In the illustration is shown a copper brew kettle with a copper lautering tub in the background, in the Croft brewery at Boston.

Physical Properties of Copper and Copper Base Alloys

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods* of Fabrication
1	Ad Aluminum	8.44	1810	0.97	0.23	Annealed tube	53		65				Fair		DD, F, R, W, B
2	Admiralty	8.54	1645-1715	1.12	0.26	Tube	50-95		5-60	5-75	17	45-180	Fair		F, R, W, B
3	Admiralty	8.52	1720	1.05	0.26	Annealed tube	50		70				Fair		
4	Admiralty	8.55	1715	1.12	0.27	Tube, light anneal	55	23	60		15	60	Fair	Fair	DD, F, R
5	Adnic	8.88	2201	0.91	0.07	Annealed strip	55	25	50		21		Fair	Yes	
6	Advance	8.9	2210	0.82	0.05	Wrought	60-100	25-75	30-35	50-65			Good	No	DD, F, R, W, B
7	Alcumite	7.75	1900	0.935		Cast	65-70	23-25	30	30		120-140	Good	No	
8	Alcunic E	8.40				Annealed strip	45	15	55				Fair		DD, F, R
	G	8.28					48	15	50						
9	Aluminum Brass	8.33		1.08		Tube	63-90	15-89	12-45	5-65	16				DD, F, R, W

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

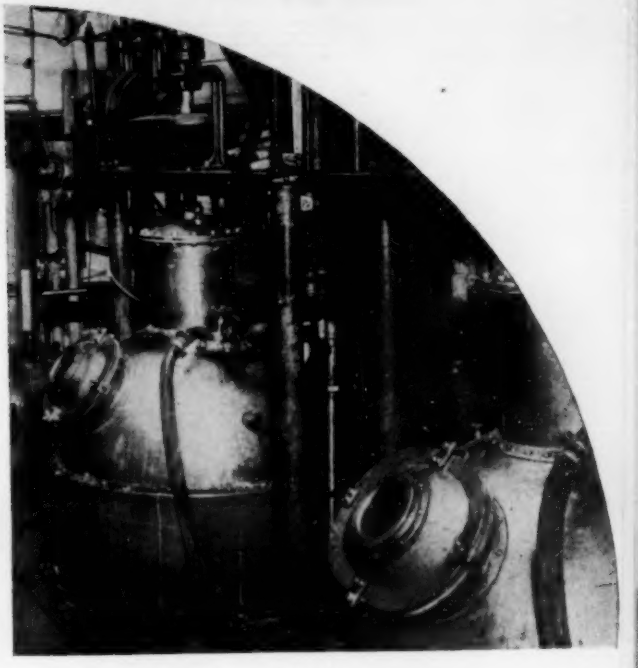
No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32–212° F. x 10⁶	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10⁻⁶	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
10	Aluminum Brass	8.32	1780	0.97	0.24	Annealed tube	52		70				Fair		
11	Aluminum Brass	8.32				Annealed strip	50	15	60				Fair	Fair	DD, F, R
12	Aluminum Bronze	7.57–8.18	1900–1960		0.15–0.18	Rod	55–125	30–70	4–75			60–190	Good		B, DD, F, R
13	Ambrac A	8.84	2100	0.91	0.092	Sheet, wire rod	50–130	24–95	2–50		19	71–160	Good		B, DD, F , R, W
14	Ambraloy 927	8.336			0.225	Condenser tubes	56.6		63				Fair		DD, W, B
15	Ampco 18	7.55	1825	1.24	0.1184	Sand cast	80–90	33–42	10–14	6–10	14.4	167–179	Free	Yes	R, W, B
16	Arcoloy					Sheet	55–60								R, W
17	Atlas 89	7.55	1825	1.1	0.122	Sand cast	70–85	25–35	15–25	15–25	13.5	120–140	Free	Fair	R, W, B
18	Auromet 11	7.60	1930–1950	0.95		Bar	80–85	30–32	30–31	29		100	Good	Yes	
19	Auromet 55	7.3–7.5	1930–1950	0.95		Bar	105–115	85–105	1.5–2	4.5–4.9		240–270	Good	Yes	
20	Beryllium Copper	8.35	1680		0.20	Heat treated hard	175	127	1.5		17.9	325	Fair	Yes	DD, F
						Heat treated soft	155	110				280			
21	Beryllium Copper	8.21	1587–1751	0.94		Quenched	70	25	45		18–19		Good	Yes	DD, F, R, W, B
						Plus heat treat	165	115	6						
22	Cataract	8.7–9.0	2250–2350	0.95		Cast	45–55		10			80–90	Good	No	C
23	Chrome Copper	8.9	1980			.080-in. wire heat treated	92	53	3				Fair	Yes	DD, F
24	Commercial Bronze	8.84	1900	0.97	0.43	Tempered rod	45		30				Excel.		
25	Copper, Tough Pitch	8.88	1981	0.98	0.922	Rod	35–55	12–44	5–35	60–70	16	42–107	Tough		DD, F, R, W, B
26	Cupaloy	8.93	1940	0.92	0.785		65–75	60–65	20–25	60	20	140–150	Good		
27	Cupron	8.9	2270–2370	0.82	0.054	Annealed	62	40	30				Good		DD, F, R, W, B
						Hardened	135	120							
28	Cupro Nickel	8.94	2192–2237	0.9	0.07–0.09	Soft tube	50–55	20–23	40		26		Fair	Fair	DD, F, R, W
29	Cupro Nickel 30%	8.94	2230	0.90	0.09	Annealed sheet	60		33				Tough		DD, F, R, W, B
36	Cusiloy A	8.50	1868	1.0	0.08	Annealed wire	60	20	50	70	15		Fair	Yes	F, R, W, B
	B	8.58	1895		0.10		50	15							
31	Deoxidized Copper	8.90	1981	0.98	0.922	Rod, wire	35–55	12–44	5–35	60–70	16	42–107	Tough		B, DD, F, R, W
32	Deoxidized Copper	8.90	1981	0.98	0.922	Rod	35–55	12–44	5–35	60–70	16	42–107	Tough		DD, F, R, W, B
33	Duronze 1	8.78	1905	0.93		Hard drawn rod	70–100		5–10	50–70			Good		DD, F, R, W, B
34	Duronze 2	8.54	1830	0.94	0.078	Sheet	50–145		5–60	30–80	15	60–200	Tough		DD, F, W, B
35	Duronze 3		1760			Rod	80–100	20–95	5–30	35			Good		W, B
36	Duronze 4	8.17	1940		0.198	Sheet	50–100		5–70				Fair		DD, F, R, W, B
37	Everbrite	8.8			0.06	Cast	75	45	14			170	Good	Good	
38	Everdur	8.54	1830	0.94	0.078	Sheet, rod	50–145	20–95	5–50	30–80	15	60–200	Good		DD, F, R, W, B
39	Herculoy	7.60	1800–1875	0.94	0.086	Rod, sheet and tube	60–125	24–120	10–65	45–75	15		Fair	No	DD, F, R, W, B
40	High Brass	8.46	1710	1.05	0.29	Sheet	46–92		3–64				Fair		DD, F, R, W, B
41	Hytensl Bronze	7.0		0.90		Cast	110	65	15	15	14.5	220	Good	Good	
42	Naval Brass	8.39	1625	1.19	0.28	Annealed wire	55	23	40	60			Fair	Yes	R, W, B
43	Nickel Silver 18%	8.74	2030		0.08	Soft sheet	60–87		3–40				Tough		DD, F, R, W, B
44	18% Nickel Silver A	8.75	2030		0.08	Annealed strip	50	21	45		18		Fair	Yes	DD, F, R, W, B
	B	8.69	1931		0.07				40		16				
45	Nickel Silver 18% A	8.75	2030		0.080	Sheet	50–90		4–40		18	77–158	Good		B, DD, F, R, W
46	Nickel Silver 18% B	8.68	1930			Sheet, wire	60–143		1–40		15		Good		B, DD, F, R, W
47	Nickel Silver 20%	8.85	2100	0.91	0.07	Annealed sheet	55		35				Tough		
48	Olympic Bronze	8.58	1880	0.94	0.08	Sheet	56–110		5–65				Fair	Yes	DD, F, R, W, B
49	Omega Ni Silver 18%A	8.75	2030			Plate, sheet	55–90		1–40				Fair		B, DD, F, R, W
50	Omega Ni Silver 18%B	8.50	1930	1.04		Plate, sheet	60–125		1–40		20		Fair		
51	Omega Phos. Bronze A	8.86	1920	0.97		Plate, sheet	45–115		5–40		16		Fair	Good	B, DD, F, R, W
52	Omega Phos. Bronze B	8.79	1875	0.99		Plate, sheet	51–130		1–50		14.5		Fair	Good	B, DD, F, R, W
53	Omega Phos. Br. 10%	8.76	1830	1.00		Plate, sheet	52–135		1–70				Fair	Good	B, DD, F, R, W
54	P-M-G Metal	8.42	1700–1750	0.96		Cast	50	18–20	15–25	30–45	15–18	125–150	Good	Good	DD, F, R, W, B
55	Phosphor Bronze	8.86				Rod	60	55	20		15	147	Excel.		W, B, Drawing
56	Phosphor Bronze	8.80	1950–2100	1.10		Cast bar	33–38		12–20			30–60	Good		
57	Phosphor Bronze 5%	8.87	1904	0.95	0.16	Sheet	60–110	23–97	5–55		18	60–140	Tough		DD, F, R, W, B
58	Phosphor Bronze 8%	8.82	1877	0.96	0.15	Sheet	55–110	25–85	3–70				Tough		DD, F, R, W, B
59	Phosphor Bronze A	8.85	1922	0.99	0.20	Strip, hard rolled	95	90	2		15		Fair to poor	Yes	DD, F, R
	C	8.81	1877	1.01	0.15		110	105							
60	Phosphor Bronze A	8.87	1904	0.95	0.16	Sheet	60–110	23–97	5–55		18	60–140	Good		B, DD, F, R, W
61	Phosphor Bronze C	8.82	1877	0.96	0.15	Sheet	55–110	25–85	3–70				Good		B, DD, F, R, W
62	Phosphor Bronze D	8.78	1832	0.98	0.121	Sheet	60–115	40–95	5–65				Good		B, DD, F, R, W
63	Phosphorized Copper	8.94	1980	0.933	0.75–0.85	Plate, tube	32–60		4–45				Tough		DD, F, R, W, B
64	Red Brass	8.75	1868	0.98	0.38	Sheet	42–50	20–70	4–43				Fair		DD, F, R, W, B
65	Red Brass	8.64	1870	0.98	0.38	Sheet	42–83		3–47				Fair		DD, F, R, W, B
66	Red Brass	8.72	1868	1.04	0.37	Annealed rod	40	16	55	80	15		Fair	No	DD, F, R, W, B
67	Red Brass 85%	8.75	1868	0.98	0.380	Tube, sheet	42–50	20–70	4–43				Good		B, DD, F, R, W
68	Resistac	7.7		0.89		Cast	75	36	18	18		100–150	Good	Good	
69	Revalon	7.3	1740–1800	1.09	0.24	Tube, hard to soft	63–83	16–75	17–52		15		Fair	No	F
70	Roman Bronze	8.40	1625	1.18	0.279		54–90	15–75	25–50		15		Good	No	
71	Sumet Leaded Bronze	9.20	1950–2050	1.20		Cast bar	18–26		8–16			30–60	Good	Yes	
72	Super Nickel	8.96	2237	0.90		Tube	65		30				Good		B, DD, F, R, W
73	Tuf-stuf	7.62	1900			Rod	75–101	45–82	10–20			150–225	Fair	Yes	
74	Wolverine Brass Tubing	8.53	1679–1728	1.04	0.29	Tube	45–70		5–65	66–75	15	53–156	Fair	Fair	DD, Extrusion
75	Wolverine Copper Tubing	8.93	1981	0.93	0.92	Tube	30–45		5–45	67–72	15–18	48–111	Tough		DD, Extrusion
76	Zilloy	7.15	781				35–45								

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

MAKERS OF COPPER AND COPPER BASE ALLOYS

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
1	**Ad-Aluminum**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 82; Zn, 15; Al, 2; Sn, 1	T
2	**Admiralty**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 71; Zn, 27.9; Sn, 1.1	P, T
3	**Admiralty**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 70; Zn, 29; Sn, 1	S, T, W
4	**Admiralty**	Scovill Mfg. Co., Waterbury, Conn.	Cu, 70; Zn, 29; Sn, 1	CR, D, S, T, W, Rod
5	**Adnic**	Scovill Mfg. Co., Waterbury, Conn.	Cu, 70; Ni, 29; Sn, 1	CR, D, S, T, W, Rod
6	**Advance**	Driver-Harris Co., Harrison, N. J.	Cu, 55; Ni, 45	HR, CR, D, P, S, W, B
7	**Alcumite**	Duriron Co., Dayton, Ohio	Cu, 90; Al, 9; Fe, 1	C, HR, Finished products
8	**Alcunic**	Scovill Mfg. Co., Waterbury, Conn.	E:Cu, 80; Zn, 17; Al, 2; Ni, 1. G: Cu, 70; Zn, 27; Al, 2; Ni, 1	CR, D, T, W, Strip, Rod
9	**Aluminum Brass**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 76; Zn, 22; Al, 2.0	P, T
10	**Aluminum Brass**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 76; Zn, 22; Al, 2	T
11	**Aluminum Brass**	Scovill Mfg. Co., Waterbury, Conn.	Cu, 76; Zn, 22; Al, 2	CR, D, T, W, Strip, Rod
12	**Aluminum Bronze**	Amer. Brass Co., Waterbury, Conn.	Cu, 88–96; Al, 2.3–10.5; Fe; Sn; Mn	B, C, CR, D, HR, P, S, T, W
13	**Ambrac A**	Amer. Brass Co., Waterbury, Conn.	Cu, 65; Ni, 20; Zn, 5	B, C, CR, D, HR, P, S, T, W
14	**Ambraloy 927**	Amer. Brass Co., Waterbury, Conn.	Cu, 76; Zn, 22; Al, 2	CR, D, P, S, T
15	**Ampco 18**	Ampco Metal, Inc., Milwaukee, Wis.	Cu, 85; Al, 11.5; Fe, 3.5	C, HR, P, S
16	**Arcoloy**	American Radiator Co., New York, N. Y.	Cu, 95; Si; P	C, S, T
17	**Atlas 89**	Ampco Metal, Inc., Milwaukee, Wis.	Cu, 89; Al, 10; Fe, 1	C
18	**Auromet 11**	Aurora Metal Co., Aurora, Ill.	Cu, 88.5–89.5; Al, 9.5–10.5; Fe, 1	Special shapes die cast
19	**Auromet 55**	Aurora Metal Co., Aurora, Ill.	Cu, 76–80; Al, 10–12; Fe, 4–6; Ni, 4-6	Special shapes die cast
20	**Beryllium Copper**	Amer. Brass Co., Waterbury, Conn.	Cu, 97.75; Be, 2.25; Ni, present	C, HR, CR, D, P, S, T, W, B
21	**Beryllium Copper**	Riverside Metal Co., Riverside, N. J.	Cu, 97.75; Be, 2.25	CR, D, P, S, W, B
22	**Cataract**	Niagara Falls Smelting & Ref. Corp., Buffalo, N. Y.	Cu; Ni	Cast ingots
23	**Chrome Copper**	Amer. Brass Co., Waterbury, Conn.	Cu, 99.05; Cr, 0.85; Si, 0.10	C, HR, CR, D, P, S, W, B
24	**Commercial Bronze**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 89; Zn, 9; Pb, 2	D, B, Rod
25	**Copper, Tough Pitch**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 99.9 plus; O, pres.	HR, CR, S, D, W, B
26	**Cupaloy**	Westinghouse Elec. & Mfg., E. Pittsburgh, Pa.	Cu, 99.35; C, 0.60; Ag, 0.05	C, HR, CR, D, B, Strip
27	**Cupron**	Wilbur B. Driver Co., Newark, N. J.	Cu, 55; Ni, 45	HR, CR, D, W, B
28	**Cupro Nickel**	Scovill Mfg. Co., Waterbury, Conn.	Cu, 70–80; Ni, 20–30	CR, D, S, T, W, Rod
29	**Cupro Nickel 30%**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 70; Ni, 30	P, T
30	**Cusiloy**	Scovill Mfg. Co., Waterbury, Conn.	A: Cu, 95.5; Si, 3; Fe, 1; Sn, 0.5. B: Cu, 96.75; Si, 1; Fe, 0.75; Sn, 1.5	D, W, Rod
31	**Deoxidized Copper**	Amer. Brass Co., Waterbury, Conn.	Cu, 99.9+; P, 0.01	B, C, CR, HR, D, P, S, T, W
32	**Deoxidized Copper**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 99.9 plus; P, pres.	HR, CR, P, S, T, W, B, D
33	**Duronze 1**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 97; Sn, 2; Si, 1	HR, CR, S, W, B, T
34	**Duronze 2**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 97; Si, 3	C, HR, CR, D, P, S, T, W, B
35	**Duronze 3**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 90.5; Al, 7.5; Si, 2.0	B
36	**Duronze 4**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 95; Al, 5	T
37	**Everbrite**	Amer. Manganese Bronze Co., Philadelphia, Pa.	Cu, 60; Ni, 30; Fe, 3; Si, 3; Cr, 3	C
38	**Everdur**	Amer. Brass Co., Waterbury, Conn.	Cu, 94.4–96; Si, 3–4.5; Mn, 1–1.1	C, HR, CR, D, P, S, T, W, B
39	**Herculoy**	Revere Copper & Brass, New York, N. Y.	Cu, 96.25; Si, 3.25; Sn, 0.50	C, HR, CR, D, P, S, T, W, B
40	**High Brass**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 66; Zn, 34	CR, D, S, W
41	**Hytensl Bronze**	Amer. Manganese Bronze Co., Philadelphia, Pa.	Cu, 63; Zn, 23; Al, 4; Fe, 3; Mn, 3	C, HR, S
42	**Naval Brass**	Scovill Mfg. Co., Waterbury, Conn.	Cu, 59; Zn, 40.25; Sn, 0.75	D, T, W, Rod
43	**Nickel Silver 18%**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 75; Ni, 18; Zn, 17	R, S, W
44	**Nickel Silver 18% A & B**	Scovill Mfg. Co., Waterbury, Conn.	A: Cu, 65; Ni, 18; Zn, 17. B: Cu, 55; Ni, 18; Zn, 27	CR, D, S, T, W, Rod
45	**Nickel Silver 18% A**	Amer. Brass Co., Waterbury, Conn.	Cu, 65; Ni, 18; Zn, 17	B, CR, D, P, S, T, W, C
46	**Nickel Silver 18% B**	Amer. Brass Co., Waterbury, Conn.	Cu, 55; Ni, 17; Zn, 27	B, CR, D, P, S, T, W, C
47	**Nickel Silver 20%**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 75; Ni, 20; Zn, 5	P, T
48	**Olympic Bronze**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 96; Si, 3; Zn, 1	C, HR, CR, D, P, S, T, W, B
49	**Omega Nickel Silver 18% A**	Riverside Metal Co., Riverside, N. J.	Cu, 65; Ni, 18; Zn, 17	B, CR, D, P, S, W
50	**Omega Nickel Silver 18% B**	Riverside Metal Co., Riverside, N. J.	Cu, 55; Ni, 18; Zn, 27	B, CR, D, P, S, W
51	**Omega Phos. Bronze A**	Riverside Metal Co., Riverside, N. J.	Cu, 95.5; Sn, 4.3; P, 0.2	B, CR, D, P, S, W
52	**Omega Phos. Bronze B**	Riverside Metal Co., Riverside, N. J.	Cu, 91.6; Sn, 8.25; P, 0.15	B, CR, D, P, S, W
53	**Omega Phos. Bronze 10**	Riverside Metal Co., Riverside, N. J.	Cu, 90; Sn, 10; P	B, CR, D, P, S, W
54	**P-M-G Metal**	Phelps-Dodge Copper Prod. Corp., New York, N. Y.	Cu, 92 min; Si, 2.0–4.0; Fe, 0.5–2.0	C, HR, CR, D, P, S, W, B, T
55	**Phosphor Bronze**	Amer. Brass Co., Waterbury, Conn.	Cu, 88; Sn, 4; Zn, 4; Pb, 4	CR, B
56	**Phosphor Bronze**	Buffalo Fdry. & Mach. Co., Buffalo, N. Y.	Cu, 88; Sn, 8–10; Zn, 2–4; P, 0.01–0.25	C
57	**Phosphor Bronze 5%**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 94.85; Sn, 5.0; P, 0.15	CR, D, S, W, B
58	**Phosphor Bronze 8%**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 91.9; Sn, 8.0; P, 0.10	CR, D, S, W, B
59	**Phosphor Bronze A & C**	Scovill Mfg. Co., Waterbury, Conn.	A: Cu, 95; Sn, 5. B: Cu, 92; Sn, 8	CR, S, W, Rod
60	**Phosphor Bronze A**	Amer. Brass Co., Waterbury, Conn.	Cu, 95; Sn, 5; P	B, CR, D, P, S, T, W
61	**Phosphor Bronze C**	Amer. Brass Co., Waterbury, Conn.	Cu, 92; Sn, 8; P	B, CR, D, P, S, T, W
62	**Phosphor Bronze D**	Amer. Brass Co., Waterbury, Conn.	Cu, 89.5; Sn, 10.5; P	B, CR, D, P, S, T, W
63	**Phosphorized Copper**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 99.9+; P, 0.02	HR, CR, D, P, S, T
64	**Red Brass**	Bridgeport Brass Co., Bridgeport, Conn.	Cu, 85; Zn, 15	HR, CR, P, S, T, W, B
65	**Red Brass**	Chase Brass & Copper Co., Waterbury, Conn.	Cu, 85; Zn, 15	S, T, W
66	**Red Brass**	Scovill Mfg. Co., Waterbury, Conn.	Cu, 85; Zn, 15	CR, D, S, T, W, Rod
67	**Red Brass 85%**	Amer. Brass Co., Waterbury, Conn.	Cu, 85; Zn, 15	B, D, HR, P, T, S, W
68	**Resistac**	Amer. Manganese Bronze Co., Philadelphia, Pa.	Cu, 88; Al, 10; Fe, 2	C, HR, P, S
69	**Revalon**	Revere Copper & Brass, New York, N. Y.	Cu, 76; Zn, 22; Al, 2	T
70	**Roman Bronze**	Revere Copper & Brass, New York, N. Y.	Cu, 60; Zn, 39.25; Sn, 0.75	W, Rod
71	**Sumet Leaded Bronze**	Buffalo Fdry. & Mach. Co., Buffalo, N. Y.	Cu, 68–72; Sn, 0–14; Pb, 14–30; Ni, 0–2	C, B
72	**Super Nickel**	Amer. Brass Co., Waterbury, Conn.	Cu, 70; Ni, 30	B, CR, D, HR, P, S, W
73	**Tuf-stuf**	Mueller Brass Co., Port Huron, Mich.	Cu, 87; Al, 10; Fe, 3	D, B
74	**Wolverine Brass Tubing**	Wolverine Tube Co., Detroit, Mich.	Cu, 70; Zn, 30	B, T
75	**Wolverine Copper Tube**	Wolverine Tube Co., Detroit, Mich.	Cu & Ag, 99.9 min.; P, 0.015–0.035 optional as deoxidizer	B, T
76	**Zilloy**	New Jersey Zinc Co., New York, N. Y.	Zn; Cu, 1.00; Mg, 0.01	Roofing and siding

** Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; Fr, forgings; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.



Nickel and Alloys

HIGH REGARD in which nickel construction is held is due to the fact that it combines mechanical properties superior to those of mild steel with a relatively high degree of corrosion resistance and good working qualities. In many instances in the chemical industries equipment is fabricated entirely of wrought nickel, while in others it is made from nickel-clad steel, which is produced by the hot rolling together of two slabs of nickel and steel in which the nickel usually constitutes 10 per cent of the total thickness.

Whether fabricated from solid or clad nickel the selection of these materials for equipment is often based on something more than the durability resulting from their high resistance to corrosion. An important consideration is often the necessity of protecting the product being handled from harmful metallic contamination. This is true in two of the largest applications of pure nickel for corrosion resistance, namely, caustic-soda production and food processing. In the case of caustic soda the use of nickel eliminates the presence of iron and other metals which may be deleterious to the alkali in certain uses. The ductility and malleability of nickel plus its ability to produce homogeneous seams by welding, and the absence of effects from physical strains, make this metal useful for numerous purposes.

Nickel plating is an effective means of giving metal surfaces added resistance to attack by chemicals. However, the degree of protection afforded by nickel plate varies with several factors, particularly the thickness of the plate, porosity of the coating and the corroding medium. Where the plated equipment is subjected to immersion in water, salt solutions, acids and alkalis, plating is but a temporary expedient.

A covering sprayed onto steel suffers from the same defects. However, sprayed nickel coatings are useful to cover other non-ferrous metals, the corrosion resistance of which, under the conditions of use, may be reasonably satisfactory.

One of the most popular of the nickel-copper alloys is Monel metal. This alloy possesses a useful degree of resistance toward more corrosives than most other materials of construction with the possible exception of the 18 and 8 alloys. Its high strength, good ductility, and ease of fabrication are of equal practical importance, since they permit its use where corrosion resistance alone would not suffice. They often determine its choice in preference to other materials of equivalent corrosion resistance but of inferior mechanical properties.

A modification of Monel metal known as K Monel contains up to 5 per cent aluminum. It has good corrosion resistance with the added advantage of increased strength and hardness after heat treatment.

The group of alloys bearing the name Hastelloy provide exceptional resistance to some of the most troublesome corrosives. The wrought alloy, Hastelloy A, which can be fabricated by all the common methods, is superior to all other strong malleable materials

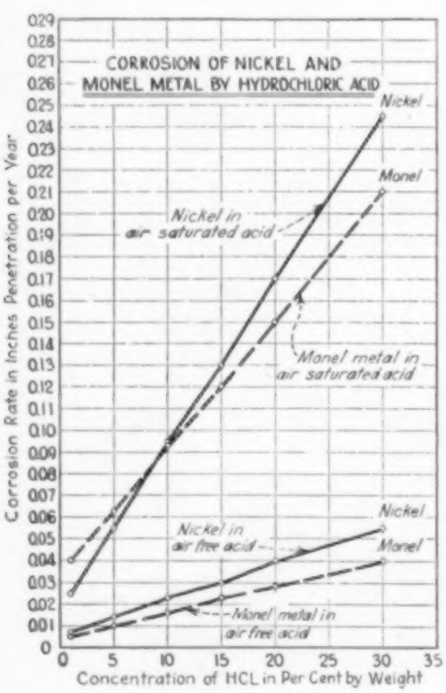
Mechanical Properties of Monel Metal in Various Forms

	Hot-rolled, Forged	Cold-Rolled and Cold-Drawn					Cast
		Annealed	Sheet Full-hard	Strip Full-hard	Rod Cold-drawn	Wire Spring-temper	
Tensile strength......psi	80-105,000	65-85,000	100-120,000	100-125,000	85-125,000	140-175,000	65-100,000
Yield point......psi	40- 85,000	25-35,000	90-110,000	90-115,000	60- 95,000	....	30- 60,000
Elastic limit......psi	25- 65,000	20-30,000	....	....	45- 65,000	....	....
Elongation (2")......%	20-45	35-50	2-8	2-5	15-35	3-8	5-35
Reduction in area......%	50-65	65-75	....	....	50-65	35-45	5-35
Brinell (500 kg.)......	125-150	80-105	....	....	215-240	....	....
Brinell (3000 kg.)......	150-175	118-135	....	....	220-250	....	105-350
Shore scleroscope......	19-23	15-17	40-45	40-45	35-45	40-50	....
Rockwell "B"......	70-80	60-68	95-100	95-105	90-100	over 100	....
Endurance limit......psi	35,000	35,000	....	....	....	....	....
Charpy impact......ft. lbs.	over 120	150	....	....	....	....	....
Izod impact......ft. lbs.	over 110	....	....	....	....	....	....

in its resistance to hydrochloric acid solutions under all conditions and in all concentrations and at temperatures up to about 160 deg. F. The cast alloy, Hastelloy C, is especially resistant to oxidizing acid salt solutions, such as ferric chloride, and to solutions containing free chlorine at atmospheric temperatures. Another cast alloy, Hastelloy D, is highly resistant to boiling concentrated sulphuric acid. Hastelloy A is used for reaction vessels, heating coils and condensers and the like. The cast alloys find application in pumps, valves, fittings, cast pipe and coils, agitators and similar equipment.

A relatively new high nickel alloy is Inconel which contains approximately 80 per cent nickel, 14 per cent chromium and 6 per cent iron. It is highly resistant to corrosion and tarnishing by food products and by dilute organic acids. It also resists many oxidizing acid salt solutions and is used extensively for photographic processing equipment. Results of exposure in a storage tank to hypo fixing solution for 154 days showed a corrosion rate of only 0.000003 in. penetration per year and there was no deposition of silver. Inconel is practically free from attack by fatty acids at elevated temperatures and is superior to most other materials in resisting corrosion by alkaline sulphur compounds.

Originally developed as an alloy for the Parr oxygen bomb calorimeter which would withstand the attack of both nitric and sulphuric acids at high pressures and temperatures, Illium G has been used in many applications in process industries where severe corrosive conditions coupled with heat and abrasion are to be found.



Resistance of Nickel and Monel Metal to Corrosion by Chlorinated Solvents

[Corrosion Rates in Inches Penetration Per Year]

Solvent	Tests at 67° to 86° F.				Tests at Boiling Point			
	Water Layer Present		Water Layer Absent		Water Layer Present		Water Layer Absent	
	Nickel	Monel	Nickel	Monel	Nickel	Monel	Nickel	Monel
Carbon Tetrachloride	0.00002	0.0001	0.000003	0.00001	0.002	0.004	0.00003	0.00004
Chloroform	0.00006	0.00002	0.00003	0.00001	0.00012	0.0045	0.0002	0.00015
Ethylene Dichloride	0.00001	0.000025	0.000007	0.00001	0.00036	0.003	0.00003	0.00003
Trichlor-ethylene	0.0004	0.0007	0.00015	0.00007	0.001	0.011	0.00002	0.00006
Carbon Tetrachloride / Ethylene Dichloride	*0.000003	0.00002	0.000003	0.00001	0.002	0.001	0.00006	0.00001

* Mixture containing 90 per cent by volume carbon tetrachloride and 10 per cent by volume ethylene dichloride.

Resistance of Nickel and Monel Metal to Corrosion by Sodium Chloride

[Corrosion Rates in Inches Penetration Per Year]

	In Saturated Brine at 180° F. in Grainer	In Saturated Salt Spray, Steam and Air at 200° F.	Alternate Exposure to Saturated Brine and Hot Air	In Oil Fired Salt Dryer — Distance From Feed End				In Steam Heated Salt Dryer — Distance From Feed End			
				8 ft.	12 ft.	20 ft.	28 ft.	8 ft.	12 ft.	20 ft.	28 ft.
Monel Metal	0.00016	0.0027	0.0002	0.011	0.009	0.007	0.009	0.0002	0.00015	0.0003	0.0002
Nickel	0.0002	0.0022	....	0.0055	0.004	0.008	0.011	0.0001	0.0001	0.0001	0.00007

Comparative Resistance of Nickel, Monel Metal and Inconel to Various Corrosives of Different Concentrations and at Different Temperatures

[Results of All Tests Expressed in Inches Penetration Per Year]

Metal	70% Caustic Soda at 200 Deg. F.	Viscose Rayon Hardening Bath* (sulphuric acid, sodium sulphate and hydrogen sulphide)	50% Sodium Sulphide at 320 Deg. F.			Mixed Fatty Acids (stearic and oleic)**	
			After 48 Hrs.	After 88 Hrs.	After 324 Hrs.	At 425 Deg. F.	At 600 Deg. F.
Monel Metal	0.0001	0.046	0.0014	0.0039	0.013	0.0027	0.0027
Nickel	0.000005	0.0015	0.071	0.038	0.022	0.004	0.002
Inconel	0.000085	0.0008	0.004	0.0026	0.0038	0.0014	0.000008

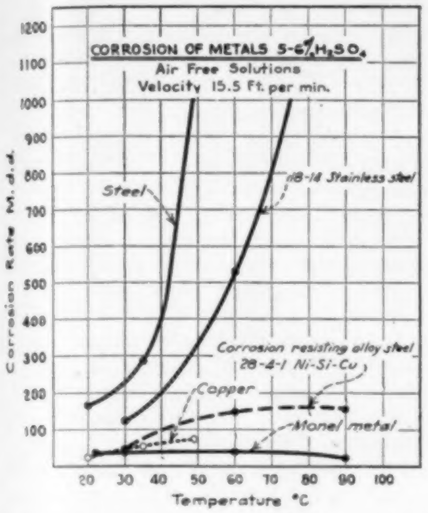
* Specimens exposed above top tube sheet of vacuum evaporator for 120 days.

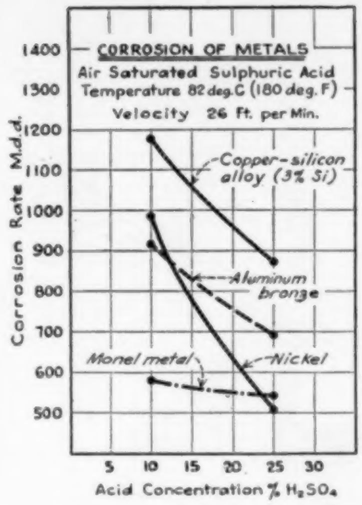
** Exposed for 2,000 hrs. in vacuum bubble tower.

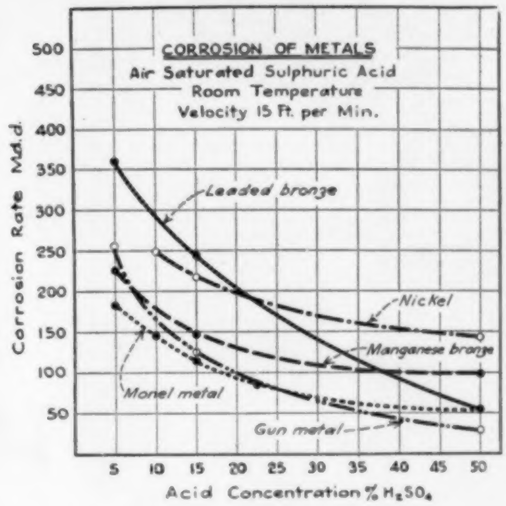
Resistance of Monel Metal to Various Corrosives

[Corrosion rates in mg./sq.dm./24 hr.]

Caustic Soda, 30-50%, 179° F. ave. (test in evaporator)	1
Saturated Sodium Chloride Solution, 180° F., no aeration	1
Sodium Chloride, 3% NaCl, 30° C., air saturated, low velocity	6
Pure Citric Acid Solution, 60-62%, 130-150° F., no aeration	3
Sulphuric Acid, 25%, 60-80° F., no aeration, low velocity	8
Sulphuric Acid, 10%, 60-80° F., no aeration, low velocity	12
Sulphuric Acid, 10%, 60-80° F., air saturated, low velocity	215
Hydrochloric Acid, 3.6%, 60-80° F., no aeration, low velocity	35
Hydrochloric Acid, 3.6%, 60-80° F., air saturated, low velocity	524
Hydrochloric Acid Pickle, 10% HCl, 70-90° F., no aeration	135
Frosting Solution, 60% HF, 130-140° F., air saturated, low velocity	51
Concentrated Nitric Acid	Very high







Corrosion Resistance of Illium G to Various Acids at Different Temperatures and Concentrations

[R-Recommended by Manufacturer. All figures refer to tests reported in Inches Penetration Per Year.]

	Sulphuric Acid						Hydrochloric Acid					Nitric Acid				Acetic Acid			
Temperature	0.5%	2.5%	10%	25%	60%	95%	0.25%	1%	3%	10%	Conc.	0.5%	5%	50%	Conc.	0.1%	0.5%	10%	Conc.
Room......	R	R	R.0003	R.0011	R	R.0001	R	R	R	R.0020	.240	R	R<.0001	R	R	R	R	R	R
100 Deg. F...	R	R	R	R.0016	R	R.0001	....	....	....	......	....	R	R	R	R	R	R	R	R
Boiling.......	R	R	R.0058	R.0189	R	.1352	....	....	....	.3595	....	R	....	....	....	....	....	....	....

PHYSICAL PROPERTIES OF NICKEL ALLOYS

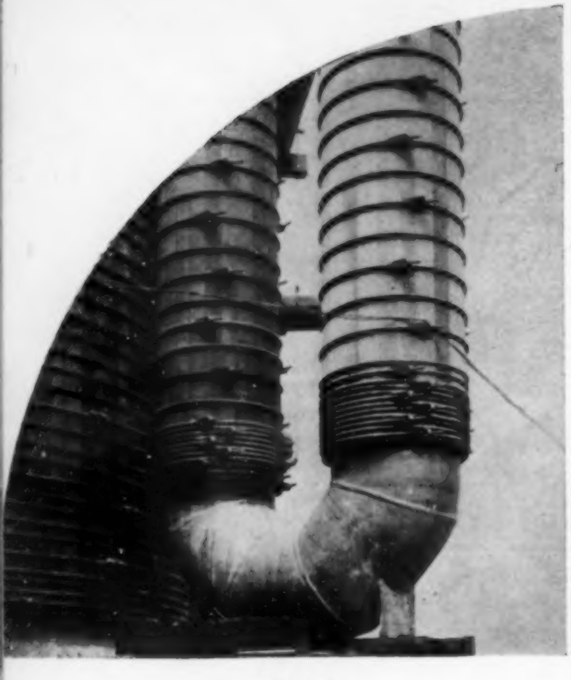
No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10⁶	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10⁻⁶	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
1	D. H. 99	8.90	2642	0.70	0.15	Wrought	60-100	25-75	30-35	50-65			Good	No	DD, F, R, W, B
2	G-60												Fair	Yes	R, W, B
3	Hastelloy A	8.8	2372-2426	0.61	0.04	Annealed	110-120	47-52	30-48	35-54	27.4	207	Good		DD, F, R, W, B
4	Hastelloy C	8.94	2320-2380	0.63	0.03	As cast	55-79	42-47	3-11	5-15		217	Machinable	Fair	W
5	Hastelloy D	7.8	2030-2050	0.61	0.05	As cast	38	38	0	0	28.5	364	Unmchble.	Good	W
6	Illium G	8.3		0.75		Cast	60	50					Fair	Yes	W
7	Inconel	8.55	2540	0.64	0.032	All	80-200	30-160	55		32	250	Tough	Yes	DD, F, R, W, B
8	Monel	8.8	2370-2460	0.77	0.06	All forms	65-175	25-150	50 max	45-75	26	220	Machinable	Yes	DD, F, R, W, B
9	Monel K	8.58	2400-2460	0.77	0.06	All forms	100-200	70-140	45 max			375	Tough	Yes	DD, F, R, W, B
10	Monel S	8.75	2350	0.69		As cast	90-115	70-90	3-1	5-1	26	280-325	Tough	Good	
11	Nichrome V	8.412	2552	0.73	0.036	Wrought	110	60	35	55			Good	No	DD, F, R, W, B
12	Nickel	8.85	2640	0.72	0.14	All forms	60-175	15-140	55 max	30-75	30.5	200	Machinable		DD, F, R, W, B
13	Nickel-clad Steel	8.0	2600-2650	0.72	0.14	Plate	55-65	27.5	27		30	90-120	Good	No	
14	Nirex	8.55	2516	0.70		Wrought	80-150	40	45	60			Good	No	DD, F, R, W, B

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

MAKERS OF NICKEL ALLOYS

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
1	D. H. 99	Driver-Harris Co., Harrison, N. J.	Ni, 99.0	HR, CR, D, P, S, W, B
2	G-60	La Bour Co., Elkhart, Ind.	Ni, 63;Cr, 24; Cu, 5; Mo, 4; W, 2; Si. 0.80; Fe, 1; Mn, 0.20; C, 0.20	C
3	Hastelloy A	Haynes Stellite Co., Kokomo, Ind.	Ni base, containing Fe and Mo	C, HR, P, S, T, W, B
4	Hastelloy C	Haynes Stellite Co., Kokomo, Ind.	Ni base, containing Fe, Cr and Mo	C
5	Hastelloy D	Haynes Stellite Co., Kokomo, Ind.	Ni base, containing Si and Al	C
6	Illium G	Burgess-Parr Co., Freeport, Ill.	Ni, 56; Cr, 24; Cu, 8; Fe; W; Mo; Si	C
7	Inconel	International Nickel Co., New York, N. Y.	Ni, 78; Cr, 13.5; Fe, 6.9; C, 0.08; Cu, 0.3; Mn, 0.35; Si, 0.35	C, HR, CR, D, P, S, T, W, B
8	Monel	International Nickel Co., New York, N. Y.	Ni, 68; Cu, 29; C, 0.15; Fe, 1.5; Mn, 1.1; Si, 0.1	C, HR, CR, S, T, D, P, W, B
9	Monel K	International Nickel Co., New York, N. Y.	Ni, 64; Cu, 30; Al, 3.45; C, 0.2; Fe, 1.5; Mn, 0.5; Si, 0.2	CR, HR, D, W, B
10	Monel S	International Nickel Co., New York, N. Y.	Ni, 64; Cu, 29; Fe, 2.5; C, 0.1; Mn, 0.5; Si, 3.75	C
11	Nichrome V	Driver-Harris Co., Harrison, N. J.	Ni, 80; Cr, 20	C, HR, CR, D, P, S, T, W, B
12	Nickel	International Nickel Co., New York, N. Y.	Ni, 99.4; Cu, 0.10; C, 0.1; Fe, 0.15; Mn, 0.15; Si, 0.1	C, HR, CR, S, T, D, P, W, B
13	Nickel-clad Steel	Lukens Steel Co., Coatesville, Pa.	Pure nickel on steel base	HR, P, S
14	Nirex	Driver-Harris Co., Harrison, N. J.	Ni, 80; Cr, 14; Fe, 6	HR, CR, D, P, S, T, W, B

** Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.



Lead and Alloys

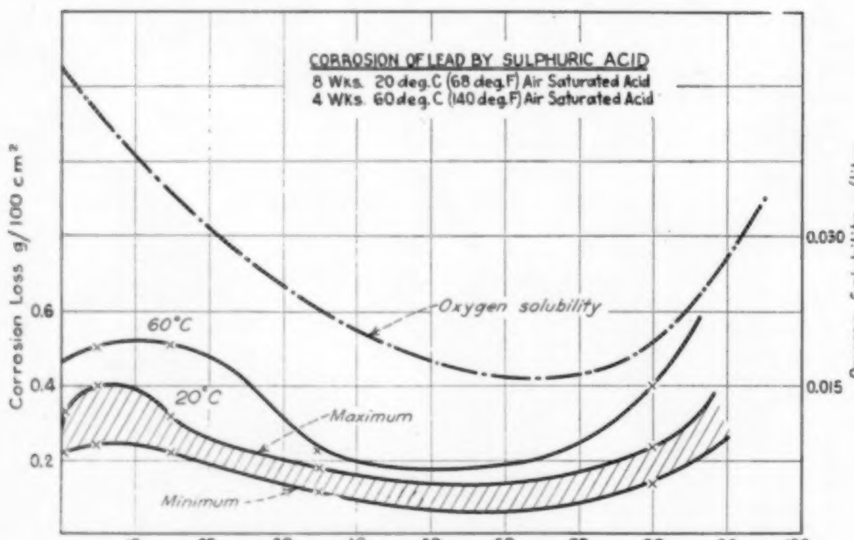
LEAD'S popularity as a material of construction is due to the combination of its resistance to many corrosive chemicals, its pliability, and its good working qualities which facilitate fabrication and repair. In the production and handling of sulphuric acid the use of lead is practically indispensable. It is also widely used in phosphoric acid production, in sulphonation and chlorination processes in the organic chemicals industry, in the pulp and paper industries, in explosive manufacture, and in the production and handling of hydrofluoric acid.

Until very recently the only two forms of the metal available were chemical lead and the hard or antimonial lead. The newly developed tellurium lead has greater tensile strength and more resistance to fatigue and corrosion than other forms of the metal. A new tellurium-antimonial lead alloy is also beginning to find important applications in a number of process industries. Tellurium alloys are said to lower costs, because they give longer service without repair. Another recent development, paralleling the rapid progress in chromium plating, is the use of a 7 per cent tin alloy for handling chromic acid solutions at both high and low temperatures.

Pulp and paper mills, particularly in the case of the sulphite process, are large users of lead. The new Weyerhaeuser pulp plant at Everett, Wash., required approximately 100 tons of lead products to resist corrosion of sulphurous compounds. Practically all lead pipe and sheet lead was made with 6 per cent antimony, but a tellurium antimonial alloy was used in certain parts of the Jenssen gas cooler shown in an accompanying illustration.

An outstanding example of corrosion resistance in a chamber-process sulphuric acid plant is reported in a case where tellurium lead is used as an anti-splash pipe for the Glover acid. Cooled acid from the Glover tower is led into a short pipe, 2½ in. in diameter, closed at the top and with a series of holes bored into the sides. All the acid from the tower flows through this pipe into the receiving tank. Ordinary lead pipe lasted only three weeks in this service. Tellurium lead has had to be replaced only after 10 or 12 months and the pipe was worn uniformly to a thin shell. A phosphoric acid plant reports that the use of a tellurium lead coil placed in an evaporator had more than double the life of an ordinary lead coil.

A Struthers-Wells horizontal tube evaporator measuring 4 ft. 6 in. in diameter and about 7 ft. high employs approximately 3,500 lb. of lead for its construction. It is used by the American Zirconium Corporation of Baltimore for concentrating a titanium sulphate solution containing 15 to 20 per cent of free sulphuric acid. With the exception of the base, which is of cast iron, the entire evaporator is made of lead alloy castings consisting of 92 per cent lead and 8 per cent antimony.



Corrosion of Lead by Sulphuric-Acid and Brine Mixture

Concentration in Per Cent: Sulphuric Acid	Concentration in Per Cent: Sodium Chloride	Temp. Deg. F.	Mg. per sq. dm. per day
8.3	1.7	59	150
		104	180
		140	200
		176	210
		212	2,200
31	17	122	1,400
		167	3,300
		212	3,600
33.3	6.7	50	8
		59	64
		104	72
		140	64
		176	310
		212	1,400

Source: "Corrosion Resistance of Metals and Alloys" by McKay and Worthington, 1936.

Manufacturer's Recommendations for Resistance to Sulphuric Acid at Various Concentrations and Temperatures.

[*R-Recommended. NR-Not Recommended.*]

	Temp.	Concentration in Percentage H_2SO_4 0.5	2.5	10	25	60	95
Chemical Lead	Room	R	R	R	R	R	R
	158 deg. F	R	R	R	R	R	NR
	Boiling	R	R	R	R	R	NR
Hard Lead	Room	R	R	R	R	R	R
	158 deg. F.	R	R	R	R	R	NR
	Boiling	R	R	R	NR	NR	NR
Tellurium Lead	Room	R	R	R	R	R	R
	158 deg. F.	R	R	R	R	R	NR
	Boiling	R	R	R	R	R	NR

Corrosion of Hard Lead by Hydrochloric Acid

Acid Conc. Per Cent	Mg. per sq. dm. per day 68 Deg. F.	212 Deg. F.
1	10	10
5	10	60
10	20	60
35	100	240

Source: "Corrosion Resistance of Metals and Alloys" by McKay and Worthington, 1936.

▲

Corrosion of Lead by Acid Mixtures

Acid Concentration—in Per Cent Sulphuric	Hydrochloric	Nitric	Mg. per sq. dm. per day
20			10
18	2		320
15	5		1,790
10	10		4,890
5	15		8,560
2	18		13,000
18		2	24,000
15		5	very great
10		10	very great
5		15	very great
2		18	very great

Source: "Corrosion Resistance of Metals and Alloys" by McKay and Worthington, 1936.

▼

Some Physical and Mechanical Properties of Lead and Alloys

A. Tensile Strength

Pure Lead Sheet	Rate 0.22 In./In. Min. Lb./In.^{2}	% Elongation on 6 in.
At 15° C.	1,570	49
At 100° C.	804	51
24 hr. at 100° C.	765	46
100 hr. at 100° C.	820	50
200 hr. at 100° C.	730	54

Tellurium-Lead Sheet	Rate .022 In./In. Min. Lb./In.^{2}	% Elongation on 6 in.
At 15° C.	2,700	48
At 100° C.	1,700	43
24 hr. at 100° C.	1,670	47
100 hr. at 100° C.	1,610	38
200 hr. at 100° C.	1,610	33

	Rate .25 In./In. Min. Lb/In.^{2}	% Elongation on 2 in.
Antimonial lead (6%)	4,400	41
Pure lead	1,600	53
Amer. chem. lead	2,200	54
Tellurium-lead	3,200	42

B. Fatigue Limits (Haigh)

Pure lead	± 446 lb./sq. in.
Amer. chem. lead	± 627 lb./sq. in.
0.06 tellurium-lead	± 1142 lb./sq. in.

PHYSICAL PROPERTIES OF LEAD ALLOYS

MATERIAL	Specific Gravity	Melting Point °F.	Mean Coeff. Therm. Exp. 32-212° F. x 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.^{2}	Yield Point 1,000 Lb. per in.^{2}	Elongation % in 2 in.	Elastic Modulus, Lb. per in.^{2} x 10^{-3}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*	Safe Working Stress, lb. per sq. in. at Deg. F.
Antimonial Lead	10.8	477–545	1.52	0.068	Rolled	4	3	39	2	9	Good	No	F, W	400 @ 70° 110 @ 248°
Chemical Lead	11.2–11.4	610–620	1.63	0.083		1.9–2.3	0.7	50	1–2	4.5–5.5	Good	No	F, W	125 @ 212° 110 @ 248° 80 @ 302°
Special Acid Lead	11.36	620	1.63	0.083	Sheet	225	0.95	50	2.5	4.2	Good	No	F, W	300 @ 77°
Tellurium-Antimonial Lead														
Tellurium Lead	11.35	620	1.63	0.083		2.8–4		30–50	1–2	5–6	Good	No	F, W	125 @ 212° 110 @ 248° 80 @ 302°

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

MAKERS OF LEAD ALLOYS

MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
Antimonial Lead	Andrews Lead Co., Long Island City, N. Y.	Pb; Sb, 3–8	B
	Eagle-Picher Co., Cincinnati, Ohio		C, S, T, W
	Flemm Lead Co., Long Island City, N. Y.		S, T, W, B
	National Lead Co., New York, N. Y.		C, CR, P, S, T, W, B
	Northwest Lead Co., Seattle, Wash.		S, T, B
Chemical Lead	(Manufacturers same as for antimonial lead)	Pb, 99.8 plus	(Same as above)
Special Acid Lead	American Smelting & Refining Co., New York, N. Y.	Pb, 99.92; Cu, 0.6; Bi, 0.02; Ag; Ni; Zn; Cd	C, HR, CR, P, S, T, W, B
Tellurium-Antimonial Lead	Andrews Lead Co., Long Island City, N. Y.	Pb; Sb; Te, 0.1 max.	S, T, B
	Northwest Lead Co., Seattle, Wash.		S, T, B
Tellurium Lead	Andrews Lead Co., Long Island City, N. Y.	Pb; Te, 0.04–0.10	S, T, B
	Eagle-Picher Co., Cincinnati, Ohio		S, T
	National Lead Co., New York, N. Y.		C, HR, CR, P, S, T, W, B
	Northwest Lead Co., Seattle, Wash.		S, T, B

** Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.

Noble Metals and Tantalum

THIS group of metals and their alloys are used for construction of equipment but, of course, in contrast to the lower cost of materials, they are to be found in relatively small quantities and only in vital spots and for extreme conditions. These metals have an immensely important role, however, for in the places where they are employed no other material may be substituted and upon their successful performance generally depends the success or failure of the operation of equipment or process. The outstanding new use for a platinum alloy is in the glass industry where it is used to cover the refractory pouring dies. The platinum-rhodium alloy prevents the serious attack on the dies by the molten glass. Other interesting developments are precious clad metals and plated surfaces. The illustration shows the use of platinum alloys for spinnerets in the rayon industry.

Noble Metals

	Au	Pt	Ir	Os	Pd	Rh	Ru	Units
Atomic weight	197.2	195.2	193.1	190.9	106.7	102.9	101.7	
Specific gravity	19.33	21.40	22.42	22.50	12.16	12.4	12.10	Grams per c.c.
Melting point	1,063	1,773	2,454	2,700?	1,550	1,985	2,450?	Deg. C.
Comparative volatility in air at 1300° C.		2	60	(1000)	6	1	200	
Specific heat	25.7	26.5			26.2			At 20° C. Joules per gr. atom.
			26.1	25		25	26	0 to 100° C. Joules per gr. atom.
Temperature coefficient of linear expansion	14.2	8.9	6.5	6.1	11.8	8.4	9.1	$\times 10^{-6}$ at 20° C.
		11.30						$\times 10^{-6}$ at 1000° C.
Hardness, Brinell: Cast		50	172		52	139	220	Baby Brinell
Hard	78	97			109	260		2 mm. ball 120 kg. load
Annealed	35	47			49	101		
Hardness, Mohs' scale	2.5	4.3	6.5	7.0	4.8		6.5	Diamond = 10
Ultimate strength: Hard	26	34			39			Kg/mm.²; 0.5-mm. wire
Annealed		15			14			Kg/mm.²; 0.5-mm. wire
Elongation: Hard		0.8			1.0			Per cent. 2 in.; 0.5-mm. wire
Annealed	25	32			24			Per cent. 2 in.; 0.5-mm. wire

Noble Metals

	Au	Pt	Ir	Os	Pd	Rh	Ru	Units
Electrical resistance at 0° C., annealed	14.68	60.0	32.1	57.1	64.8	30.7	87.0	Ohms per mil. ft.
Temp. coef. of resistance per ° C.: Hard		0.003917			0.0037			0–100° C.
Annealed	0.00398	0.003923						0–100° C.
Annealed		0.00318			0.00236			0–1200° C.

Tantalum and Alloys

Properties	Tantalum	Vascoloy — Ramet D
Specific gravity	16.6	15.5
Melting point deg. F.	5162	
Mean. coeff. thermal exp. 32–212 deg. F. X10⁶	0.357	0.34
Therm. Conduc. C.G.S. units, room temp.	0.13	0.06
Form for which tensile prop. recorded	Annealed sheet	Trans. rup. test beam
Tensile strength 1,000 lb. per in.	50	220
Elongation % in 2 in.	35	
Reduction of area, %	30	
Elastic modulus, lb. per in.² $\times 10^{-6}$		56
Brinell hardness	70	
Rockwell A		88.5
Machining qualities	Like mild steel	Mach. with diamond
Abrasion resistant	Yes	Very

Makers of the Noble Metals and Tantalum

MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
Gold	Baker & Co., Inc., Newark, N. J.	Au	
Iridium	Baker & Co., Inc., Newark, N. J.	Ir	
Palladium	Baker & Co., Inc., Newark, N. J.	Pd	
Platinum	Baker & Co., Inc., Newark, N. J.	Pt	
Tantalum	Fansteel Metallurgical Corp., North Chicago, Ill.	Ta, 99.95 plus; C, 0.01; Fe, 0.001	C, R, D, S, T, W, B
Vascoloy-Ramet D	Vascoloy-Ramet Corp., N. Chicago, Ill.	Ta C, 80; W, 12; Ni, 8	

** Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; Fr, forgings; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.

SILVER equipment is generally made entirely of the one metal. Fine silver is preferred for most applications; sterling and coin silver are not so resistant although their strength is greater. The initial cost of this type of equipment is high because of the large quantity of metal involved but much of it may be salvaged when the vessel is scrapped. Three types of linings are available: (1) linings which are fitted in without being permanently attached to the outer wall; (2) electro-plated linings, and (3) clad metal walls. Cast silver is seldom used. Silver-lined equipment is not used when a vacuum or high pressure is employed, especially if the equipment is large and is operated at a high temperature. It may be easily fabricated by spinning, drawing, or other operations, soldered either with soft solder or silver solder, and joined by autogeneous gas welding. The steam jacketed kettles illustrated have a silver lining $\frac{1}{8}$ in. thick.

Silver and Alloys

Effect of Annealing on the Properties of 0.032 In. Gage Fine Silver Reduced 50 Per Cent in Thickness Compared With Previous Anneal

Temp. of 30-Min. Anneal	Scleroscope Reading	Rockwell Number $\frac{1}{16}$-In. Ball 60 Kg. Load	Cupping Test Depth, In.	Cupping Test Pressure, Lb.	Yield Strength [1] Lb./Sq. In.	Tensile Strength, Lb./Sq. In.	Elongation 2 In. %
As rolled	27	91.0	....	....	44,300	54,300	2.4
200° F.	27	91.0	0.140	750	....	....	....
400° F.	11	49.0	0.301	1,000	16,000	26,500	43.7
600° F.	9	39.0	0.328	1,000	13,200	25,000	51.6
800° F.	8	33.0	0.332	1,000	11,500	25,000	51.5
1,000° F.	7	30.0	0.330	950	10,600	24,100	50.8
1,200° F.	6	11.5	0.331	1,000	7,900	22,900	53.9
1,400° F.	6	9.8	0.327	1,000	7,800	22,500	48.4

Source: From data furnished by Handy and Harman, Bridgeport, Conn.

[1] Yield strength values determined by noting when dividers set for 2 in. pulled out of gage marks.

Attack of Various Chemicals

Severe attack	Slight attack
Hydrogen sulphide+moisture.	Ammonia gas.
Ammonium hydroxide+chloride	Oxygen below 400° C.
Chlorine vapor+moisture	Phenol.
Iodine vapor+moisture	Oxalic acid.
Bromine vapor+moisture	Hydrofluoric acid.
Potassium cyanide	Tri-sodium phosphate.
Hydrobromic acid	Di-sodium phosphate.
Hydriodic acid	Sodium hydroxide.
Hydrogen selenide	Potassium hydroxide.
Pyrosulphuric acid	Sodium chloride.
	Fluorine vapor below 100°C.
	Liquid ammonia free from chlorides.

Source: Silver: Its Properties and Industrial Uses, U. S. Bureau of Standards Circular C412 (in press.)

Corrosion Resistance of Fine Silver

Nitric Acid — All concentrations	Poor
Sulphuric Acid — Less than 1.71 Sp. Gr.	Good
Sulphuric Acid — Concentrated	Poor
Hydrochloric Acid — All concentrations	Fair [1]
Phosphoric Acid — All concentrations	Good [2]
Citric Acid — All concentrations	Excellent
Acetic Acid — All concentrations	Excellent
Oxalic Acid — All concentrations	Excellent
Formic Acid — All concentrations	Excellent
Hydrofluoric Acid — All concentrations	Excellent
Hydrobromic Acid — All concentrations	Poor
Hydriodic Acid — All concentrations	Poor
Ammonium Hydroxide — All concentrations	Excellent
Sodium Hydroxide — All concentrations	Excellent
Potassium Hydroxide — All concentrations	Excellent
Sodium Chloride — All concentrations	Fair
Ferrous Sulphate — Hot solutions	Poor
Ferric Sulphate — Hot solutions	Poor
Alkali Sulphides — All concentrations	Poor
Alkali Cyanides — All concentrations	Poor
Oxygen Gas — All temperatures below melting point	Excellent
Halogen Gases — Room temperature	Good
Hydrogen Sulphide Gas — Room temperature	Poor

[1] HCl attacks silver but immediately forms protective film of silver chloride which is fairly resistant to all concentrations.

[2] Unpublished data obtained in laboratories of Handy and Harman of Bridgeport, Conn., show that silver 999.5 fine lost only about 3 mg. per cm.^{2} per day when immersed in 85 per cent H_3PO_4 solution at 112 to 121 Deg. C.

Source: Bulletin No. 4, Handy and Harman.

Makers and Physical Properties of Silver and Alloys

MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32–212° F. $\times 10^6$	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.^{2}	Yield Point, 1,000 Lb. per in.^{2}	Elongation, % in 2 in.	Rockwell B Hardness
Coin Silver	Handy & Harman, New York, N. Y.	Ag, 90; Cu, 10	10.35	1435–1615		Hard	70–75	60–65	5–7	80–90
	American Platinum Works, Newark, N. J.					Annealed	35–40	25–30	30–35	30–40
Fine Silver	Handy & Harman, New York, N. Y.	Ag, 99.9	10.53	1955	1.06	Hard	40–45	35–40	6–10	50–56
	American Platinum Works, Newark, N. J.					Annealed	20–25	15–20	40–50	5–15
Sterling Silver	Handy & Harman, New York, N. Y.	Ag, 92.5; Cu, 7.5	10.40	1435–1635	0.94	Hard	67–72	55–60	4–6	75–85
	American Platinum Works, Newark, N. J.					Annealed	35–40	20–25	30–35	25–40

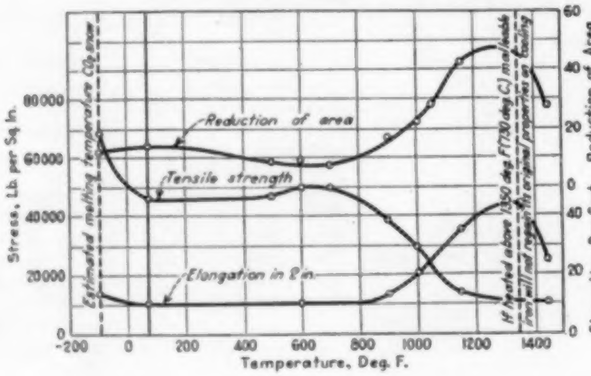
Cast, Ingot, Wrought Irons

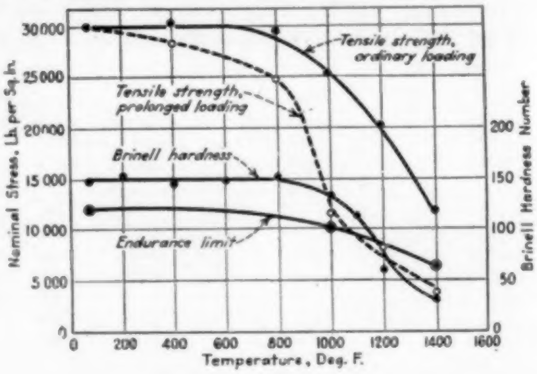
ORDINARY cast iron is not corrosion-resistant to so large a number of chemicals as are the alloyed steel or special alloys, but it does possess sufficient immunity to make its use economical in many cases where corrosion is a factor. The facility with which it may be cast into intricate shapes, its ability to fill out very thin sections, the ease with which it may be machined and its low cost, recommend it for many uses. In recent years cast iron has been improved in quality by refinements in foundry practice, by altering the basic ratios of carbon and silicon, and more recently by the addition of alloying elements such as nickel, chromium, molybdenum and copper.

Ingot iron is a highly refined iron produced by the basic openhearth process.

Wrought iron is a commercially pure iron. Illustration shows jacketed cast iron kettles. (Courtesy Buffalo Foundry & Machine Co.)

Left—Tensile properties of malleable cast iron. Right—Results of tests at high temperatures
(Bolton and Bornstein, A.S.T.M. Symposium on Effects of Temperature on Properties of Metals, 1931)





Physical Properties of Cast, Ingot and Wrought Irons

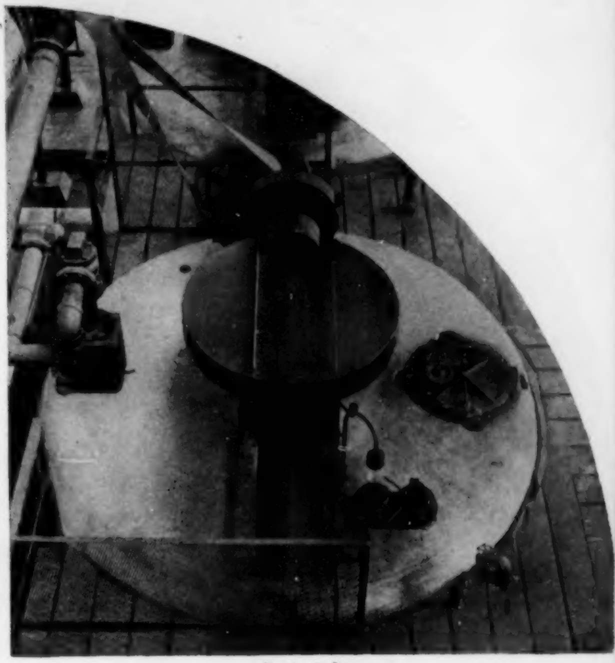
No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10⁶	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10⁻⁶	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
1	**Armco Ingot Iron**	7.87	2795	0.70	0.16	Hot rolled	42–48	26–32	22–28	65–78	30	82–100	Excel.	No	DD, F, R, B, W
2	**Buflokast Gray Iron**	7.20	2150	0.60		Cast bar	25–50	None	0	0		100–500	Good	Yes	
3	**Genuine Wrought Iron**	7.70	2700–2800	0.67		Plate	48	27–30	14	40–45	29	97	Excel.		F, R, W, B
4	**Genuine Wrought Iron**	7.86	2750–2900	0.65		Bar	48	28			28		Good	Yes	F, R, W, B
5	**Mac Hempite**	7.60	2400–2600	0.60	0.12	Bar				45				Yes	R, W, B
6	**Ni-Hard**	7.40	2150–2250			Cast	30–40		0	0		575–750	Fair	Good	C
7	**Tisco Flintmetal**						25					550–600	Unmchble	Good	

* Methods of fabribation: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

Makers of Cast, Ingot and Wrought Irons

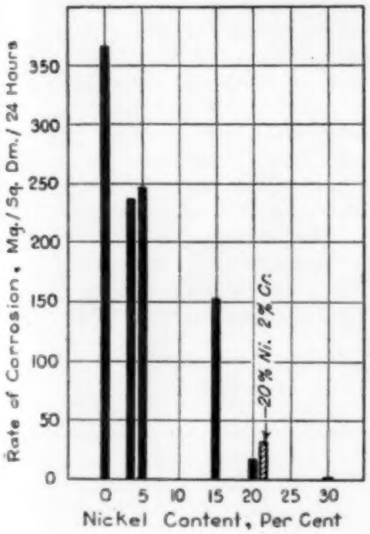
No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
1	**Armco Ingot Iron**	Amer. Rolling Mill Co., Middletown, Ohio	Fe; C, 0.012; Mn, 0.017; P, 0.005; S, 0.025; Si, trace	C, HR, CR, D, P, S, T, W, B
2	**Buflokast Gray Iron**	Buffalo Fdry. & Mach. Co., Buffalo, N. Y.	Fe; C, 3–4; Cr, 0–2; Ni, 0–20; Mn, 0.60–1.50	C
3	**Genuine Wrought Iron**	A. M. Byers Co., Pittsburgh, Pa.	Fe; C, 0.05 max; Mn, 0.05 max; Si, 0.10–0.15; P; S	HR, P, S, T, B
4	**Genuine Wrought Iron**	Reading Iron Co., Reading, Pa.	Fe, 98.8; C, 0.03; P, 0.15; S, 0.025–0.03	HR, P, S, T, B
5	**Mac Hempite**	Mackintosh-Hemphill Co., Pittsburgh, Pa.	Fe; C, 0.4–3.0; Ni, 1.5–3.5; Mn, 0.7–4.0; Cr, 0–1.25; Mo, 0–0.75	C
6	**Ni-Hard**	International Nickel Co., New York, N. Y.	Fe; C, 2.75–3.6; Ni, 4.4–4.6; Cr, 1.4–1.6; Si, 0.5–1.5; Mn, 0.3–0.7	C
7	**Tisco Flintmetal**	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; C, 3.00–3.50; Cr, 1.25–1.75; Ni, 4.0–4.5; Mn, 0.4–0.7	C

** Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.



Austenitic Cast Irons

CAST IRONS containing sufficient nickel or nickel and copper to produce a stable austenitic structure in the normal casting operation were developed ten or twelve years ago. Resistance of these irons to heat and chemical attack has resulted in a relatively broad application in chemical engineering equipment. They have a higher coefficient of thermal expansion than the ordinary product, and a lower thermal conductivity. The comparative ductility and easy machinability give them considerable advantage. Rotary and reciprocating pumps, valves, pipe lines and reaction vessels operating on sulphuric acid mixtures, petroleum refinery liquors, caustic and numerous salts, show economies when fabricated of austenitic cast iron. The loading doors on the vessel in the illustration are Ni-Resist castings employed to resist corrosion.



Effect of nickel on the resistance of cast iron to corrosion by caustic soda. This test was made in an evaporator concentrating caustic soda from 100° Tw. to 130° Tw. (Data from International Nickel Co.)

Corrosion Resistance of Ni-Resist

(Corrosion rates in mg./sq. dm./24 hr.)

Atmosphere	Ni-Resist (Rusts Superficially)	Plain Cast Iron (Rust Readily)
Atmosphere 30 days exposure	9.5	50.7
Atmosphere 90 days exposure	7.9	63.5
Atmosphere 1½ years exposure	3 to 4	30 to 40
Water Spray test piece vertical	6.6	207.5
Water Spray test piece horizontal	17.6	244.0
Aerated Tap Water immersion test	7.8	67.2
3% Sodium Chloride (aerated)	50	190
CO_2 Sat'd Tap Water 95° C.	110	660
7% Ferric Sulphate Solution	17,000	32,000
5% Sulphuric Acid (aerated)	350	30,000
5% Hydrochloric Acid (aerated)	507	26,665
10% Hydrochloric Acid (aerated)	598	29,475
20% Hydrochloric Acid (aerated)	1,111	33,270
Hot Caustic (in evaporator concentrating 100–130 Tw.)	30	430

Physical Properties of Austenitic Cast Irons

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10⁶	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10⁻⁶	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication
1	Ni-Resist	7.5–7.6	2150–2275	1.0		Cast	20–35		2 max	0	17–19	120–170	Good	Yes	Castings
2	Ni-Resist (Cu-free)	7.5–7.6	2150–2275	1.0		Cast	20–35		2 max	0	17–19	120–170	Good	Yes	

Makers of Austenitic Cast Irons

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available
1	Ni-Resist	International Nickel Co., New York, N. Y.	Fe; C, 2.75–3.1; Ni, 12–15; Cu, 5–7; Cr, 1.5–4; Mn, 1–1.5; Si, 1.25-2	Castings
2	Ni-Resist (Cu-free)	International Nickel Co., New York, N. Y.	Fe; C, 2.2–3; Ni, 15–20; Cr, 2.5 Max.; Mn, 1–1.5; Si, 0.6–2	Castings

High-Silicon Irons

CAST irons containing in the neighborhood of 14 to 15 per cent silicon have been well known in the heavy chemical industries for a quarter of a century. The optimum silicon content is apparently about 14.5 per cent. A higher percentage of this alloying material is said to cause a loss of strength, and an increase in brittleness without a compensating increase in corrosion resistance. As a rule these alloys contain 0.60 to 0.80 per cent carbon. Greater carbon is said to cause increasing difficulty with the castings due to carbon segregation and voids. However, the higher carbon content tends to soften the metal, and thus to make it possible to do some finishing processes by means of machine tools, instead of by grinding wheels.

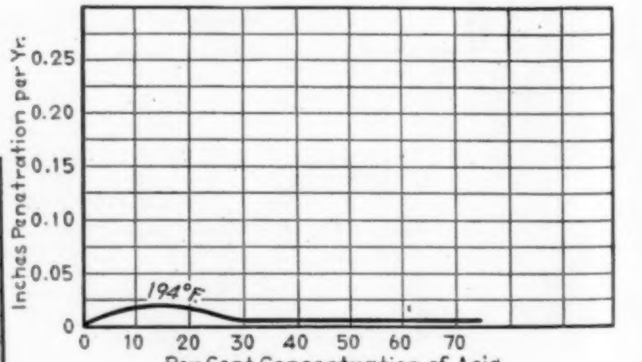
One of the limitations to a more general usefulness of these high silicon irons is the comparatively low tensile strength and susceptibility to impact. However, remarkable improvements in foundry practice have been made by American manufacturers and the metal is now made more sound than formerly. Due to the difficulty of machining these irons are confined to castings. Welding is readily accomplished by the oxy-acetylene flame, with careful pre-heating and after-cooling of the parts welded. The weld is as acid-resistant as the rest of the casting. Molten high silicon alloys are quite fluid, and the torch must be handled somewhat more rapidly than in the welding of cast iron. Special welding rod must be used.

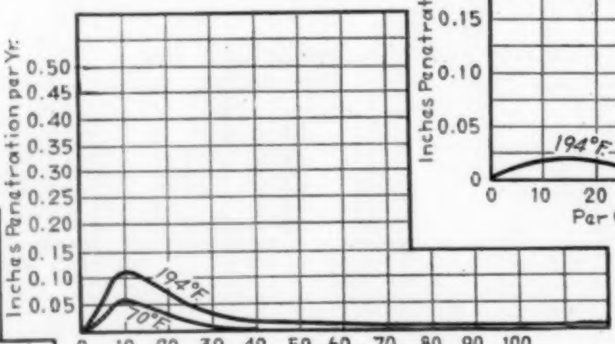
The castings have a wider range and greater resistance to acids than most other metals. Some of the more common acids that have little or no effect at any concentration or temperature are: nitric, sulphuric, acetic, phosphoric, citric and tartaric. Cold hydrochloric acid at all concentrations may be handled satisfactorily but the hot acid attacks high silicon irons (without molybdenum) readily, except very weak solutions. Recently a special high silicon iron containing 3 to 4 per cent molybdenum has been developed that is satisfactory for the handling of hydrochloric acid of all strengths, at all temperatures below the boiling points. This alloy possesses physical and chemical properties similar to those high silicon irons without the molybdenum.

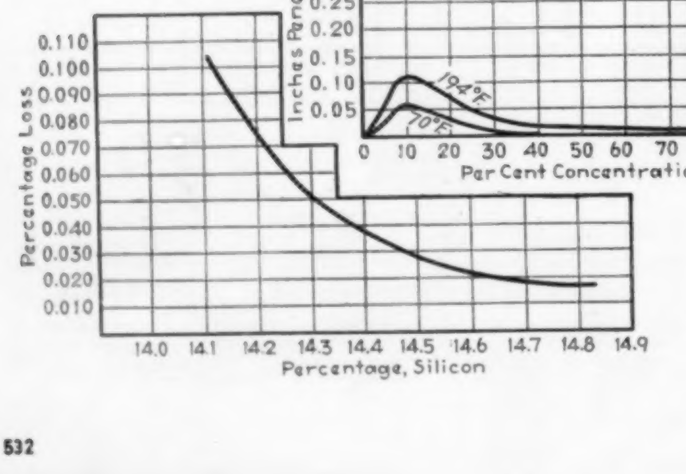
Solutions which more or less readily attack high silicon irons are: sulphurous acid, fluorine and its compounds, hot hydrochloric acid, hot ferric chloride. The halogens, in general, may attack the metal under some conditions.

The accompanying illustration shows a Duriron pump handling sulphuric acid.

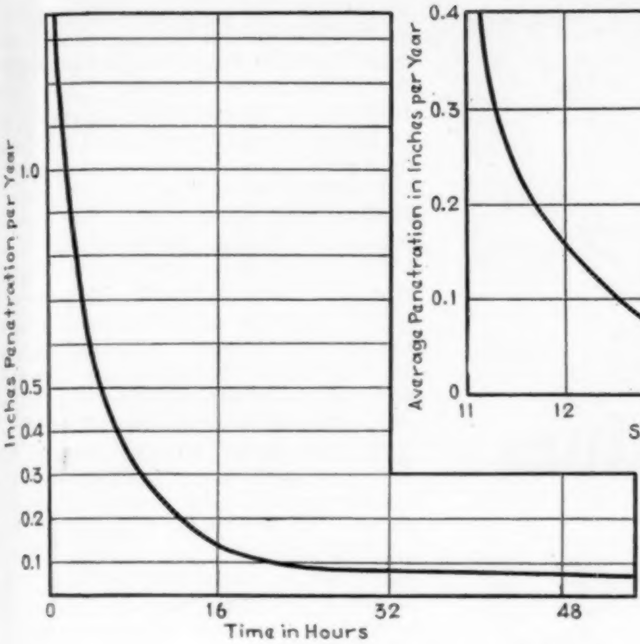
Right—Resistance of high-silicon irons to nitric acid of various concentrations in 8-hour test. Agitated solutions.

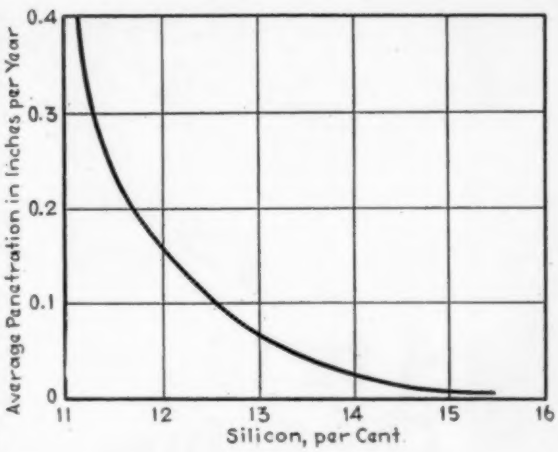






Center—Action of hot and cold sulphuric acid of various concentrations on high-silicon irons, 8-hours, agitated solutions. Bottom—Effect of 25 per cent sulphuric acid at 194 deg. F., 8 hour, agitated solutions, on iron silicides with varying iron silicon ratios, other elements constant. (Data from Duriron Co.)



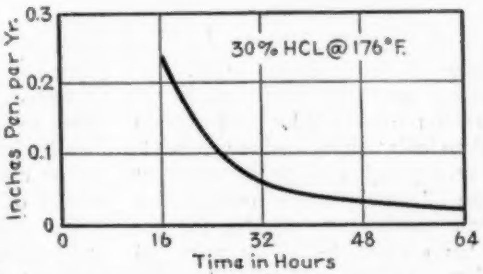


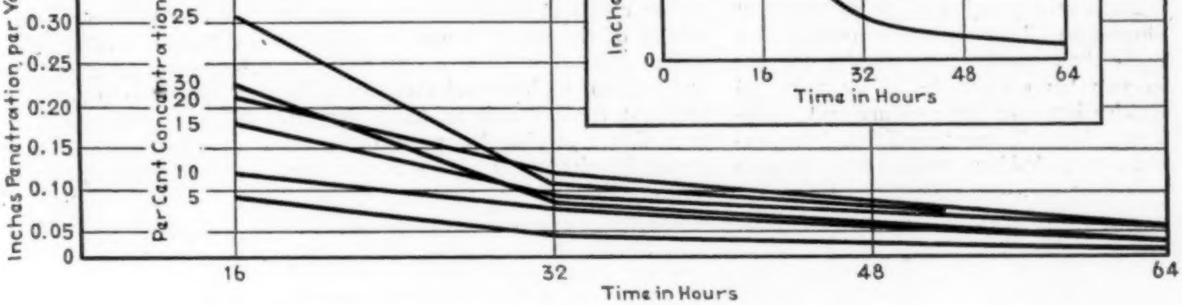
Extreme left—Resistance of a high-silicon iron containing 3 per cent molybdenum to 20.2 per cent hydrochloric acid. The specimen was weighed each hour during first 16 hour interval. (Source Duriron Co.)

Left—Effect of silicon content on the corrosion of ferro-silicon alloys in 25 per cent sulphuric acid at 194 to 212 deg. F. (Source, Speller, Corrosion, Causes and Prevention.)

Below—The diagram illustrates the corrosion-time rates for completely ground surfaces of the high-silicon iron containing molybdenum. Relative flatness indicates speed at which stable surface films are built up in a comparatively short time. Thin films of this are especially resistant to the triple action of stress, corrosion and abrasion.

Below—Corrosion resistance of the high-silicon iron containing molybdenum in hydrochloric acid. Rate of inches penetration per year in acid of various concentrations at 176 deg. F. Air agitated solutions.



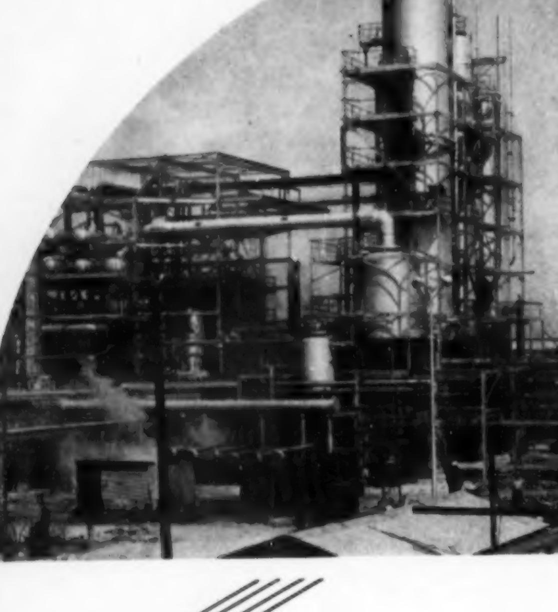


Physical Properties of High Silicon Cast Irons

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32–212° F. x 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.^{2}	Yield Point, 1,000 Lb. per in.^{2}	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.^{2} x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication
1	Antaciron	7.1	2350	0.70	0.13	Pipe	Modulus of rupture, 19,500		0	0		R'k'w'l C 38–48	Grinding only	Yes	Welding
2	Corrosiron	7.02	2400–2600		0.09	Cast	18		0	0		300	Ground or turned	Yes	Casting
3	Durichlor	7.0	2350	0.36		Cast	17					Sclero-scope 48	Grinding only	Yes	
4	Duriron	7.0	2300	0.36		Cast	16					Sclero-scope 50	Grinding only	Yes	Welding
5	Tantiron		2400									260	Grinding only	Yes	

Makers of High Silicon Cast Irons

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available
1	Antaciron	Antaciron Inc., Raritan, N. J.	Fe, 85; Si, 14.5	Castings
2	Corrosiron	Pacific Foundry Co., San Francisco, Calif.	Fe; Si, 14.25–14.5; C, 0.80–1.10	Castings
3	Durichlor	Duriron Co., Dayton, Ohio	Fe; Si, 14.5; Mo, 3	Castings
4	Duriron	Duriron Co., Dayton, Ohio	Fe; Si, 14.5; C, 0.8; Mn, 0.35	Castings
5	Tantiron	Bethlehem Foundry & Mach. Co., Bethlehem, Pa.	Fe; Si, 13.5; C, 0.8–1; Mn, 0.04; P, 0.18; S, 0.15	Castings



4 to 10 Chromium Steels

GREATER STRENGTH and resistance to scaling at high temperatures, and greater resistance to the corrosion of sulphides and certain other chemicals than ordinary steels feature this group of 4 to 10 per cent chromium alloys. These characteristics make them particularly suitable for use in petroleum refineries. The principal applications are for pressure still equipment, hot oil transfer lines, heat exchangers, bubble tower caps, return bends, valves and fractionating column parts. The greater strength, resistance to scaling, and corrosion make it possible to use thinner walled tubing thereby increasing the thermal efficiency of the unit and materially reducing the weight of the entire equipment.

The steels are four to ten times as resistant to sulphide and three times as resistant to oxidation at 1,000 deg. F. as ordinary steels. In general, the increase in chromium above 3 per cent gradually improves the physical properties and also the corrosion resistance. At temperatures between 1,200 and 1,300 deg. F. there is little advantage to be gained in using these steels for long time service, as their creep strength is only slightly above that of carbon steel (unless, perhaps, tungsten or molybdenum is added). However, at these temperatures the short time ultimate strength is approximately 50 per cent higher than that of carbon steel, which results in a greater factor of safety against adverse conditions. Through their use the number of failures at these temperatures has been reduced.

Recently several modifications of the 4 to 6 per cent have been developed and are now available at slightly increased costs. Molybdenum improves the strength and resistance to creep at elevated temperatures and reduces the tendency towards temper brittleness after long exposure at high temperatures. The resistance to corrosion and scaling is not materially affected. The addition of tungsten to these low-chromium steels produces improved strength at elevated temperatures to a considerable degree and improves their resistance to certain chemicals. Titanium or columbium renders them nonhardenable and more resistant to oxidizing media. They retain their toughness after relatively long periods of exposure at temperatures between 750 to 1,200 deg. F.

Illustration shows Beaumont, Texas, refinery of Magnolia Petroleum Co.

Creep Test Data

0.139 per cent Carbon, 4.63 per cent Chromium, 0.54 per cent Molybdenum Steel

Specimen Number[d]	Temperature of Test		Load, lb. per sq. in.	Duration of Test, hr.	Initial Elongation, per cent		Secondary Elongation, per cent per hr.	Final Elongation, per cent		Izod Impact Resistance After Creep Test[a], ft.-lb.		Rockwell Hardness Number, "B" scale, 1/16-in. ball, 100-kg. load
	Deg. Fahr.	Deg. Cent.			Front	Back		Front	Back	Keyhole-Notch Specimen	V-Notch-Specimen	
C-L	b	b	....	....	....	....	....	....	....	46	101	73
C-L7	1100	595	4 100	1 271	0.027	0.012	0.000105	0.204	0.183	c	c	....
C-L6	1100	595	4 700	1 180	0.072	0.011	0.000182	0.333	0.310	42	....	71
C-L4	1100	595	5 250	1 445	0.041	0.026	0.000417	0.753	0.732	44	....	72
C-L1	1100	595	7 500	362	0.021	0.055	0.0065	2.733	2.764	44	....	72
C-L3	1100	595	10 000	47	0.072	0.076	>0.08	3.932	3.930	43	....	71
C-T	b	b	....	....	....	....	....	....	....	46	71	74
C-T3	1100	595	3 250	1 346	0.006	0.025	0.000044	0.124	0.159	....	61	75
C-T2	1100	595	5 250	835	0.053	0.015	0.00089	0.835	0.800	43	....	72
C-T1	1100	595	6 040	742	0.036	0.036	0.0015	1.273	1.264	44	....	71
D-L	b	b	....	....	....	....	....	....	....	....	104	83
D-L2	1100	595	5 250	1 180	0.069	0.004	0.00053	0.867	0.890	46	....	81
D-T1	1100	595	5 250	721	0.029	0.031	0.000532	0.619	0.618	....	83	83
A-L	b	b	....	....	....	....	....	....	....	....	101	73
A-L1	1100	595	5 250	1 177	0.033	0.031	0.00052	0.729	0.765	....	99	76
B-L	b	b	....	....	....	....	....	....	....	....	111	81
B-L1	1100	595	5 250	336	0.033	0.038	0.001930	0.912	0.890	....	110	81
E-L	b	b	....	....	....	....	....	....	....	....	11	76
E-L2	1100	595	5 250	1 205	0.07	0.014	0.000030	0.185	0.077	....	12	75
C-L8	1200	650	3 000	1 482	0.011	0.022	0.000426	0.680	0.665	c	c	....
C-T4	1200	650	3 000	1 176	0	0.019	0.000976	0.952	0.960	....	50	74

a Impact specimens 0.380 by 0.394 in. with notch in direction of 0.394 in. dimension. Depth of notch reduced to 0.065 to give standard breaking section.

b Tested for impact resistance as heat treated. Not subjected to creep test.

c Used for short-time tension test at same temperature as creep test.

d Identification of the various test specimens shows the heat treatment A, B, C, D, or E used the direction of the test specimen in the still tube (longitudinal L or transverse T), and the specimen number 1, 2, 3, and others.

Treatment C... Normal annealing treatment. 1550 F, one hour, furnace cool to 1500 F., then 25 F. per hr. to 1300 F.; then furnace cool to 1000 F.; then air cool.

Treatment A... Same as treatment C, followed by reheating to 1425 F. for 6 hr.; then furnace cool.

Treatment B... 1550 F., one hour, air cool, reheat to 1425 F. for 6 hr.; then furnace cool.

Treatment D... 2100 F., one hour, air cool, reheat to 1425 F. for 6 hr.; then furnace cool.

Treatment E... 2100 F., one hour, furnace cool to 1500 F., then 25 F. per hour to 1300 F.; then furnace cool to 1000 F.; then air cool.

(H. C. Cross and E. R. Johnson, Creep Properties of 5 Per Cent Chromium, 0.5 Per Cent Molybdenum Steel Still Tubes, American Society for Testing Materials, Vol. 34, p. 80, 1934.)

Effect of W and Mo on the Wrought Alloy

Analysis — %	Yield	Ultimate	Elongation
4-6 Cr, 0.14 C	29,200	61,050	38.8
4-6 Cr, 0.5 Mo, 0.14 C	31,250	62,100	37.6
4-6 Cr, 1 W, 0.14 C	34,130	70,200	35.2

Effect of Ti on Castings

	Without Ti	With Ti
Tensile strength	212,000	70,100 lb. per sq. in.
Yield point	117,000	44,700 lb. per sq. in.
Proportional limit	40,700	20,500 lb. per sq. in.
Elongation in 2 in.	2.5%	8.5%
Rockwell hardness	C-45	C-1

(Data from G. F. Comstock; Book of Stainless Steels, Thum)

High-Temperature Strength of Castings

Containing 0.5 Per Cent Mo

	850 deg. F.	1000 deg. F.
	Short time tensile tests	
Ultimate strength	96,000	75,000 lb. per sq. in.
Yield point	73,000	50,000 lb. per sq. in.
Elongation in 2 in.	14	22%
Reduction of area	42	60%
	Creep Stress	
1% in 10,000 hr.	35,000	10,000 lb. per sq. in.

(Data from H. W. Maack; Book of Stainless Steels, Thum)

Effect of Ti on the Wrought Alloy

(Cr, 5.4%; C, 0.11%; Ti, 0.75%)

	As Rolled	Air Cooled From 750°C (4 hr.)	Air Cooled From 900°C (10 min.)
Yield point	37,000	28,000	29,000
Ultimate strength	65,000	61,000	62,000
Elongation in 2 in.	32%	37%	44%
Reduction of area	70%	78%	80%
Izad impact, ft.-lb.	30	63	112
Brinell hardness	163	112	112

(Data from E. C. Wright; Book of Stainless Steels, Thum)

Physical Properties of the 4 to 10 Chromium Steels

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
1	B & W 440	7.8		0.66	0.087	Annealed	66	27	38	76	29	136	Good	No	R, W, B
2	4-6% Chrome-Moly					Annealed	60	25	30	60		170	Satisftory.	No	F, R, W
3	Circle L 10	7.83	2750	0.66	0.110		120	90	17	45		240	Good	Fair	
4	Crane No. 5					Cast and heat-treated	110	80	18	30		220-245			
5	Croloy 5M	7.8		0.65	0.105	Annealed	60	25	30		30	163	Fair		F, W
6	Croloy 9	7.8	2600-2650	0.63		Annealed	70-85	30-45	28-35		30	150-180	Machinable		F, W
7	Enduro 4-6% Cr		2800			Annealed	65	30	25		30	170	Good	Fair	DD, F, R, W
8	Enduro 4-6% Cr Mo	7.85	2800			Annealed	65	30	25		30	170	Good	Fair	W, DD, F, R
9	Low Chrome	7.7				Cast	90	65	15	35			Good	Yes	
10	Lo Cro 46					Air cooled from 1300° F	95	81	24	73		175			W
11	Lo Cro 46 Mo					Tests at 800°-1200° F	51-80	50-65	24-18	84-66		167		Good	W
12	Lo Cro 46W					Tests at 800°-1200° F.	66-103	50-90	24-18	85-68					
13	Silcrome 46-M	7.7	2780	0.61	0.087	Annealed bar	80-95	50-65	25-30	60-75		180-210	Fair	Good	W, DD, F, R
14	Tisco Chromol 53						130-140	115-120	10-15	30-35		280-300	Machinable	Yes	

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

Makers of the 4 to 10 Chromium Steels

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
1	B & W 440	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 4-6; C, 0.10 max and 0.25 max; Mo, 0.40-0.65	C, W
2	4-6% Chrome-Moly	Timken Steel & Tube Co., Canton, Ohio	Fe; Cr, 4.0-6.0; C, 0.15 max; Mo, 0.45-0.65; Si, 0.5 max; S; P	HR, D, T, B
3	Circle L 10	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 5.50; C, 0.20; Mo, 0.55	
4	Crane No. 5	Crane Co., Chicago, Ill.	Fe; Cr, 4-6; C, 0.35 max; Mo, 0.40-0.60	C
5	Croloy 5M	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 4-6; C, 0.25 max; Mn, 0.50 max; Mo, 0.45-0.65	HR, CR, T
6	Croloy 9	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 8-10; C, 0.15 max; Mn, 0.50 max; Mo, 1.25-1.75	HR, CR, T
7	Enduro 4-6% Cr	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 4-6; C, 0.25 max; Mn, 0.5 max; Si; P; S	HR, CR, D, P, S, T, W, B
8	Enduro 4-6% Cr Mo	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 4-6; C, 0.25 max; Mo, 0.4-0.6; Mn, 0.5 max; Si; P; S	HR, CR, D, P, S, T, W, B
9	Low Chrome	Warman Steel Casting Co., Huntington Park, Calif.	Fe; Cr, 5	C
10	Lo Cro 46	Crucible Steel Co., New York, N. Y.	Fe; Cr, 4-6; C, 0.25 max.	
11	Lo Cro 46 Mo	Crucible Steel Co., New York, N. Y.	Fe; Cr, 4-6; C, 0.25 max; Mo, 0.40-0.60	
12	Lo Cro 46W	Crucible Steel Co., New York, N. Y.	Fe; Cr, 4-6; C, 0.25 max; W, 0.75-1.25	
13	Silcrome 46-M	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 4-6; C, 0.25 max; Mo, 0.4-0.6; Mn, 0.50 max.	HR, D, P, S, W, B
14	Tisco Chromol 53	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 4.0-6.6; C, 0.15-0.35; Mn, 0.45-0.85; Mo, 0.40-0.65 or W, 0.80-1.25	C

** Forms available; B, bars; C, castings; CR, cold rolled; D, drawn; HR, hot rolled; P, plates; S, sheets; T, tubing; W, wire.

Low-Carbon Stainless Steels

THE range of stainless steels containing less than 0.12 per cent carbon includes two groups of alloys. One of these is comprised of steels containing from 11 to 16 per cent chromium and the other, known as the chromium ferrite group, contains steels of from 16 to 20 per cent chromium.

Steels of the 11 to 16 per cent chromium group have many applications in the process industries. While their corrosion resistance is not particularly high, it increases with the chromium content and is superior to that of the ordinary steels. These steels, especially in the lower chromium range, have excellent mechanical properties, and they have often been used because of these characteristics, with corrosion resistance entirely secondary.

Marked effects can be obtained by the additions of comparatively small amounts of other metals. Silicon tends to cause grain growth, lower the impact value, increase resistance to corrosion by some chemicals and especially resistance to oxidation. Sulphur has been added to promote ready machining. The sulphur is introduced as a metallic sulphide, usually that of zirconium or molybdenum. Molybdenum improves not only machinability but also forging, rolling, pickling and working. The presence of vanadium has very definitely improved the workability of the steel. Steels containing tungsten have been offered for seamless pipe for service at high temperatures. Nickel raises the tensile properties of the cast material.

The low-carbon stainless steels are successfully used for nitric acid equipment where the more concentrated acids are handled. They hold their strength at elevated temperatures and will resist scaling at temperatures under 1,600 deg. F. Other applications include shafting used under moist conditions (see illustration of welded float shafting and castings), parts subject to high and low pressure steam, coal screens, pump rods, cutting materials, and jordan bars for making paper pulp.

The chromium ferrites, which contain 16 to 18 per cent chromium and low carbon, are among the most useful of the straight chromium alloys. They possess good ductility, are easily worked hot or cold, do not work harden excessively, have excellent corrosion resistance, and are reasonable in cost. They are comparatively soft and cannot be hardened by heat treatment. Consequently these alloys are not used extensively where strength is a primary requirement. Their greatest use is in the form of flat rolled products, such as sheets, plates and strip, where loads are moderate or are carried by supporting structures and where high corrosion resistance is the ruling consideration. Due to the ductility and forming characteristics there is practically no limit to the products that may be formed or fabricated. The coefficient of expansion of the scale formed at high temperatures is similar to that of the metal itself. Thus there is no tendency for the scale to be thrown off on alternate heating and cooling. Oxidation is resisted up to about 1600° F., depending upon surrounding conditions.

The addition of silicon to these steels appears to be without noticeable advantage unless in amounts greater than one per cent, whereupon there is increased resistance to cold acids, such as nitric, sulphuric, citric, and oxalic. Copper additions improve the resistance to salt water, hydrochloric and sulphuric acids to some extent. The principal achievement of small amounts of nickel is the improvement of the physical properties and greater hardening capacity. In small amounts, molybdenum improves the resistance to dilute mineral and organic acids. Titanium or columbium is often added when maximum ductility is desired.

The outstanding application for this group of alloys is its use in the fabrication of equipment for the production of nitric acid from ammonia.

Physical Properties of a Typical 11 to 16 Per Cent Chromium Steel, Carbon 0.12 Max.

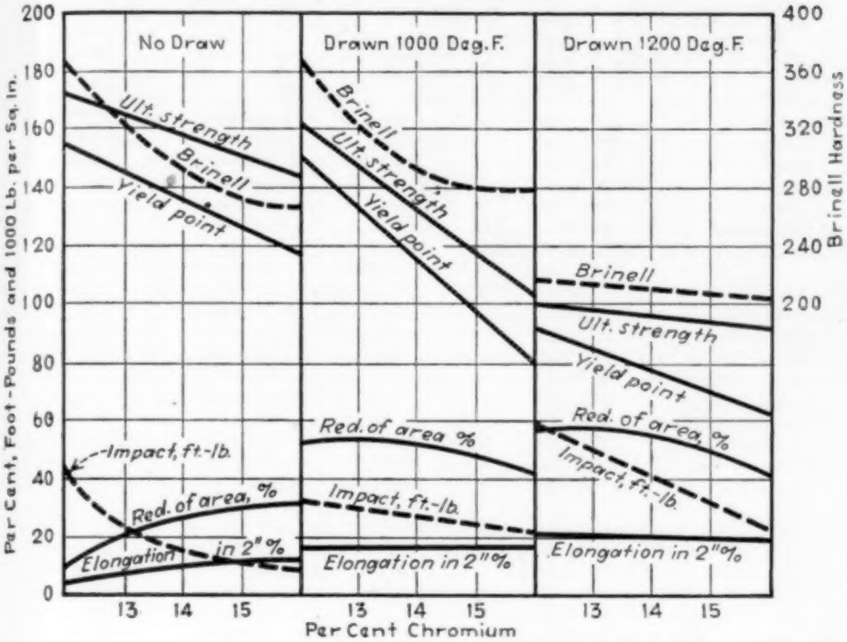
Room temperature, quenched in oil from 1800 deg. F.

Tempered At	Prop. Limit	Yield Point	Tensile Strength	Elongation in 2"	Reduction of Area	Charpy Ft. Lbs.	Brinell
400° F........	78,000	179,000	182,000	18.0%	62.8%	57.0	363
500° F........	85,000	176,000	179,000	17.1%	62.3%	60.6	363
600° F........	106,000	173,000	179,000	16.0%	61.4%	58.8	363
700° F........	105,000	174,000	179,000	17.8%	63.3%	57.9	363
800° F........	110,000	176,000	180,000	17.7%	62.6%	43.6	363
900° F........	112,000	162,000	181,000	19.8%	63.1%	15.4	363
1000° F........	66,000	168,000	175,000	17.2%	65.4%	6.0	363
1050° F........	......	112,000	135,000	21.2%	71.3%	....	269
1100° F........	66,000	105,000	119,000	21.8%	69.9%	40.7	241
1200° F........	54,000	86,000	106,000	23.9%	71.7%	128.3	228
1300° F........	48,000	82,000	97,000	26.6%	70.9%	144.0	187
1400° F........	44,000	70,000	90,000	28.4%	73.5%	144.3	183

Crucible Steel Co. of America

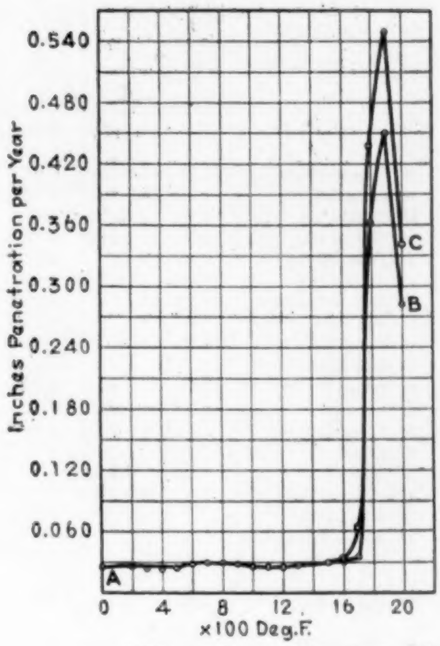
Note on Tempering: In the case of low carbon, 11 to 16 per cent chromium steels, it is desirable to avoid tempering between 800 and 1100 deg. F. because of a marked deterioration of strength properties, coincidental with which is a noticeable decrease in corrosion resistance. Impact value reaches a minimum in this range but recovers fully upon tempering at 1100 deg. F. Consequently, these steels are seldom recommended for applications requiring a brinell hardness between 240 and 300.

Effect of Chromium Content on Physical Properties of Low Carbon Stainless Steels



Thum, *The Book of Stainless Steels*

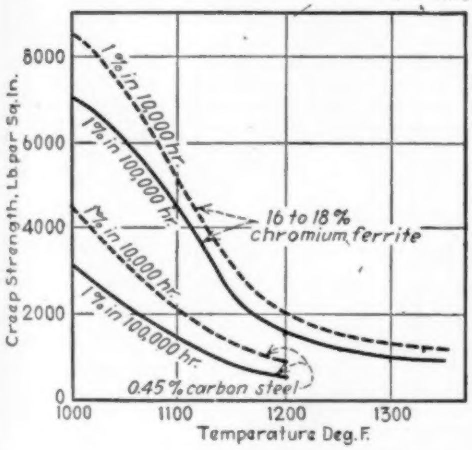
Corrosion of Chromium Ferrite in Boiling Nitric Acid



Bellinger, *Chem. & Met.*, 37, p. 691

Creep Strength, Chromium Ferrites

Stress Causing Creep of 1% in 10,000 and 100,000 Hr.



Thum, *The Book of Stainless Steels*

Physical Properties of Chromium Ferrites, Showing Effect of Titanium and Columbium

	Tensile Strength Lb. per sq. in.	Yield Point Lb. per sq. in.	Elongation in 2 in.	Reduction of Area	Brinell Hardness
Analysis: Cr, 16 to 18%; C, 0.10% max.; Mn, 0.50% max.; Si, 0.50% max.					
Hot rolled	90,000	70,000	23.0%	50.1%	170
Annealed	80,000	45,000	30.0	60.0	150
Cold drawn	180,000	90,000	12.0	50.0	228
Cold drawn plus anneal	70,000	50,000	32.1	70.2	150
Analysis: Cr, 18.65%; C, 0.13%; Ti, 0.78%					
As rolled	71,500	40,000	31%	69%	131
Air cooled after 4 hr. at 1380° F.	76,000	50,000	29	66	131
Air cooled after 20 min. at 1650° F.	68,000	40,000	32	66	118
Analysis: Cr, 19.20%; C, 0.07%; Cb, 1.00%					
As rolled	72,000	52,000	22	41	149
Air cooled after 4 hr. at 1380° F.	60,500	43,000	31	65	137
Air cooled after 20 min. at 1650° F.	72,000	45,000	29	63	118

Becket and Franks

PHYSICAL PROPERTIES OF 11 TO 16 CHROMIUM, LOW CARBON STEELS

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32–212° F. x 10⁶	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10⁻⁶	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
1	Allegheny 33		2710–2720	0.60	0.096	Annealed bar	75	45	35	75	28	150	Good		DD, F, R, W, B
2	Armco 13						65	35	30						
3	Armco 15						70	40	27						
4	Avesta 393	7.73		0.90	0.070	Heat treated	125	95	23	65		280			
5	Avesta 393-S	7.72		0.90	0.070	Heat treated	123	79	27	57		232			
6	Bethadur 410	7.77	2600–2750	0.60	0.057	Annealed	75	40	34	68	28	143	Good	Fair	DD, F, R, W, B
						Tempered	150	125	18–30	57–72		300			
7	Bethalon 416	7.76	2600–2750	0.60		Annealed	74	43	30	50		156	Excel.	Fair	W, B
						Oil quenched	150	115	20	40		300			
8	Carpenter Stainless 1	7.770	2525–2725	0.57	0.096	Annealed	85	60	30	77	28.5	175	Fair	Yes	DD, F, R, W, B
						Hardened	180	160	15	60		364			

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

PHYSICAL PROPERTIES OF 11 TO 16 CHROMIUM, LOW CARBON STEELS (Continued)

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
9	Carpenter Stainless 5	7.78	2525-2725	0.63	0.096	Annealed	86	63	25	58	28	187	Excel.	Fair	F, R, B
						Hardened	164	140	11	31		351			
10	Carpenter Stainless D-1	7.75	2525-2725	0.61	0.082	Annealed	80	50	35	80	28.5	170	Fair	Fair	DD, F, R, W, B
11	Circle L-12	7.78	2600-2725	0.56	0.096	Rolled bar	75-95	45-60	18-24	30-50		150-190	Good		
12	Colonial 410	7.76	2650	0.57	0.05	Bar, rolled, treated	128	113	21	55		269	Fair	No	
13	Colonial 410F	7.76	2650	0.57	0.05	Bar, rolled, treated	130	110	18	50		261	Excel.	No	DD, FR, W, B
14	Croloy 18	7.72		0.52	0.072	Annealed	70-85	40-60	25-30		28-30	140-185	Machinable	Slightly	F, W
15	Defirust	7.778		0.593	0.060	Bar	75	45	35	75	29	150	Good	Good	R, W, B
16	Defirust (machining)	7.77		0.58	0.059	Bar	75	45	35	63	29	150	Excel.	Good	R, B
17	Durco D-12					Cast	90	50	20	30		200-425	Good	Good	W
18	Duro-Gloss C1	7.75				Hot rolled	70	40	35	70		143	Good	Yes	DD, W, B
19	Duro-Gloss FM	7.7				Hot rolled	70	40	35	70		143	Excel.	Yes	DD, W, B
20	Enduro FC	7.75	2775	0.61	0.05	Annealed bar	100	70	20	50	28	228	Good	Fair	
21	Enduro S	7.75	2775	0.61	0.05	Annealed sheet	75	40	22		28	179	Good	Fair	DD, F, R, W
22	Enduro S-1	7.75	2775	0.61	0.05	Annealed sheets	80	40	22		28	187	Fair	Fair	DD, F, R, W
23	Lesco L	7.65	2724	0.72		Annealed bar	78	65	25	65		170	Good		DD, F, R, W, B
24	Lesco M	7.63	2724	0.72		Annealed bar	66	44	25	65		163	Good		DD, F, R, W, B
25	Midvaloy 13-00	7.82	2525-2725	0.7	0.096	Wrought	70-200	40-165	13-28	53-70	30	180-400	Good		DD, F, R, W, B
26	Milwaloy 13														
27	Nirosta Calduro KM1	7.8			0.096	Cast	80-110	60-90	10-25	30-40			Good	Yes	
28	Rezistal 12	7.75		0.59	0.096	Annealed	87	60	31	74	28-30	170	Fair		R, W
						Hardened	182	179	18	62		363			
29	Rezistal FM2	7.75		0.59	0.096	Annealed	85	51	28.5	60	28-30	184	Good		R, W
						Hardened	134	76	6.5	7.6		278			
30	Silcrome 12	7.77	2700	0.61	0.096	Heat treated	110-120	90-105	18-22	60-70	28	210-240	Good	Good	R, W
31	Silcrome 12EZ	7.77	2700	0.61	0.096	Heat treated	85-95	50-60	20-25	50-60	28	180-210	Good	Good	None
32	Silcrome 12-2	7.65	2650	0.61	0.070	Heat treated and drawn	100-220	60-170	10-25	25-60	30	250-450	Fair	Good	W, B
33	Sivyer 66	7.7	2600-2700	0.58		Cast	75-170	45-130	8-25	15-50		175-350	Good	Yes	W, B
34	Stainless FC	7.77		0.58	0.046	Heat treated	105	80	20	45		175-355	Good		
35	Stainless FMS	7.74	2650	0.57	0.05	Bar, rolled, treated	119	107	19	62		241	Free	No	DD, F, R, W, B
36	Stainless T	7.77		0.58	0.046	Annealed	85	58	33	70	30	165	Good		
						Hardened	165	160	17.5	60		395			
37	Stainless Iron														
38	Tisco 132						70-90	40-55	18-24	25-45		160-180	Good	No	
39	Uniloy 1409	7.80		0.59	0.06	Annealed	70	35	25	50	28	180	Fair	Fair	F, R
						Heat treated	180	150	18	40		350			
40	USS 12	7.6	2750-2790	0.61	0.06	Annealed	65-80	35-50	35	65	29	140-165	Fair	Yes	DD, F, R, W

PHYSICAL PROPERTIES OF CHROMIUM FERRITES

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
1	Allegheny 66	7.7	2714	0.58	0.082	Annealed bar	70	40	35	70	28	140	Good		DD, F, R, W, B
2	Armco 17	7.71		0.59	0.06		75	45	27		29				DD, W, R
3	Avesta 249	7.6		0.92	0.06	Cold rolled	66	37	35	65		160			
4	B & W 900	7.65		0.55	0.058	Annealed	75	40	27	55	29	160	Excel.	No	DD, F, R, W, B
5	Bethadur 430	7.7	2730-2760	0.59	0.057	Annealed	75	45	28	57	29	170	Fair	No	DD, F, R
6	Carpenter Stainless 6	7.73	2500-2700	0.65	0.07	Annealed	80	45	27.5	62	28	170	Good	Fair	DD, F, R, W, B
7	Chrome Stainless	7.7				Cast	90	45	15	30					
8	Colonial 610	7.8	2650			Rolled bar, annealed	78	51	32	61		176	Fair	No	DD, F, R, W, B
9	Colonial 610F	7.8	2650	0.61		Rolled bar, annealed	76	49	28	49		169	Free	No	DD, F, R, W, B
10	Cooper Alloy 16	7.6	2700	0.58	0.082	Cast	72	45	10	15		200	Good	No	
11	Duro-Gloss C2	7.7				Hot rolled	78	50	35	70		163	Fair	Yes	DD, W, B
12	Enduro AA	7.7	2725	0.60	0.045	Annealed	80	50	25		28	179	Fair	Fair	DD, F, R, W
13	Lesco H	7.61	2724	0.58		Annealed bar	74	50	27.5	61		163	Fair		DD, F, R, W, B
14	Rezistal 17	7.72		0.58	0.072	Annealed	75-85	45-55	30-40	50-60	28-30	150-190	Fair		DD, R
15	Rezistal 20	7.70		0.58	0.072	Annealed	75-85	45-55	30-40	50-60	28-30	150-190	Fair		DD, R
16	Rustless 17	7.71		0.62	0.06	Bar	75	45	35	65	29	160	Fair	No	R, W, B
17	Silcrome 17	7.67	2700	0.60	0.075	Annealed at 1350° F.	70-80	45-55	23-30	50-60	29	160-180	Fair	Good	DD, F, R
18	Silcrome RA	7.67	2700	0.61	0.07	Annealed bar	70-80	40-60	25-35	55-75	29	160-200	Fair	Good	DD, F, R, W, B
19	Sivyer 67	7.6	2600-2700			Cast	85-105	55-70	10-20	15-35		160-190	Fair		
20	Stainless C-2	7.8	2650	0.61		Rolled bar, annealed	75	50	32	55		170	Fair	No	DD, F, R, W, B
21	Stainless I	7.75	2650	0.60		Bar, rolled, treated	116	104	22	70		241	Fair	No	DD, F, R, W, B
22	Stainless M														
23	Tisco 131						75-100	45-60	5-12	6-15		190-210	Good	No	
24	Uniloy 1809	7.72		0.59	0.058	Annealed	65-85	40-50	25	50	28-30	140-190	Fair	No	DD, F, R, W
25	USS 17	7.6	2710-2750	0.60	0.058	Annealed	75-90	40-55	27	55	29	175	Fair	Yes	DD, F, R, W

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

MAKERS OF 11 TO 16 CHROMIUM, LOW CARBON STEELS

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
1	Allegheny 33	Allegheny Steel Co., Brackenridge, Pa.	Fe; Cr, 12-16; C, 0.12; Mn, 0.50	C, HR, CR, D, P, S, T, W, B
2	Armco 13	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 12-14, C, 0.12 max.	
3	Armco 15	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 14-16, C, 0.12 max.	
4	Avesta 393	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 14.0; C, 0.08	HR, CR, D, P, S, T, W, B
5	Avesta 393S	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 14.5; C, 0.08 max; Mo, 1.0	HR, CR, D, P, S, T, W, B
6	Bethadur 410	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 12.5; C, 0.10; Mn, 0.30; Ni, 0.20	HR, D, P, B
7	Bethalon 416	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 13; C, 0.10; Mn, 0.30; Ni, 0.25; S, 0.30-0.50	HR, D, B
8	Carpenter Stainless 1	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 12.5; C, 0.10	HR, CR, D, P, S, T, W, B
9	Carpenter Stainless 5	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 14; C, 0.10; S, 0.30	C, HR, CR, D, W, B
10	Carpenter Stainless D-1	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 15; C, 0.10	C, HR, CR, D, P, S, T, W, B
11	Circle L 12	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 13; C, 0.10; Ni, 0.5 max.	
12	Colonial 410	Vanadium Alloys Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 13.5; C, 0.12 max; Ni, 0.8; Mn, 0.35	HR, D, P, W, B
13	Colonial 410F	Vanadium Alloys Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 13.5; C, 0.12 max; Ni, 0.8; Mn, 0.20	HR, CR, D, S, W, B
14	Croloy 18	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 15-18; C, 0.12 max; Mn, 0.50 max; Si, 0.50 max.	C, HR, CR, T
15	Defirust	Rustless Iron and Steel Corp., Baltimore, Md.	Fe; Cr, 12-14; C, 0.12 max.	HR, CR, D, W, B
16	Defirust (machining)	Rustless Iron and Steel Corp., Baltimore, Md.	Fe; Cr, 12-14; C, 0.12 max; S, 0.50 max.	HR, D, W, B
17	Durco D-12	Duriron Co., Dayton, Ohio	Fe; Cr, 12.0; C, 0.12	C
18	Duro-Gloss C1	Jessop Steel Co., Washington, Pa.	Fe; Cr, 12-14; C, 0.12 max; Mn, 0.50 max.	HR, CR, P, S, B
19	Duro-Gloss FM	Jessop Steel Co., Washington, Pa.	Fe; Cr, 12-15; C, 0.12 max; Mn, 0.50; S, 0.25-0.35	HR, CR, P, S, B
20	Enduro FC	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 12-15; C, 0.12 max; Mn, 0.5 max; Mo, 0.45-0.65; P; S	B
21	Enduro S	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 14-16; C, 0.12 max; Mn, 0.5 max; Si, 0.5 max.	HR, CR, D, P, S, T, W, B
22	Enduro S-1	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 12-14; C, 0.12 max; Mn, 0.6 max; Si, 0.5 max.	HR, CR, D, P, S, T, W, B
23	Lesco L	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 12; C, 0.10 max; Mn, 0.4; Si, 0.5 max.	HR, CR, D, P, S, W, T, B
24	Lesco M	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 15-18; C, 0.10 max; Mn, 0.4; Si, 0.5 max.	HR, CR, D, P, S, W, T, B
25	Midvaloy 13-00	Midvale Co., Philadelphia, Pa.	Fe; Cr, 15 max; C, 0.12 max.	C, HR, B
26	Milwaloy 13	Milwaukee Steel Foundry Co., Milwaukee, Wis.	Fe; Cr, 12-14; C, 0.08-0.12	
27	Nirosta Caldure KM1	Warman Steel Casting Co., Huntington Park, Calif.	Fe; Cr, 13; Ni, 1.75 optional	C
28	Rezistal 12	Halcomb Steel Co., Syracuse, N. Y. Crucible Steel Co., New York, N. Y.	Fe; Cr, 12-15; C, 0.12 max.	
29	Rezistal FM2	Halcomb Steel Co., Syracuse, N. Y. Crucible Steel Co., New York, N. Y.	Fe; Cr, 12-15; C, 0.12 max; Mo, 0.5 max; S, 0.45 max.	
30	Silcrome 12	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 12-14; C, 0.12 max; Mn, 0.50 max.	HR, D, P, S, W, B
31	Silcrome 12-EZ	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 12-15; C, 0.12 max; Mn, 0.50 max; Mo, 0.65 max; S, 0.40 max.	HR, D, W, B
32	Silcrome 12-2	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 12-15; C, 0.12 max; Mn, 0.70 max; Ni, 1.25-2	HR, D, W, B
33	Sivyer 66	Sivyer Steel Casting Co., Milwaukee, Wis.	Fe; Cr, 12-14; C, 0.12 max; Mn, 0.5	C
34	Stainless FC	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 12-15; C, 0.12 max; S, 0.35 max; Mo, 0.40	HR, CR, D, S, W, B
35	Stainless FMS	Vanadium Alloys Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 13.5; C, 0.12 max; Mn, 0.20	HR, D, P, S, W, B
36	Stainless T	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 12-16; C, 0.12 max.	HR, CR, D, S, W, B
37	Stainless Iron	Henry Disston & Sons, Inc., Tacony, Philadelphia, Pa.	Fe; Cr, 13; C, 0.12 max; Mn, 0.4 max.	HR, P, S, B
38	Tisco 132	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 11.5-16.0; C, 0.10 max; Mn, 0.40-0.60	C
39	Uniloy 1409	Universal Steel Co., Bridgeville, Pa.	Fe; Cr, 11.5-14; C, 0.07-0.15; Mn, 0.25-0.7	HR, CR, D, P, S, W, B
40	USS 12	Carnegie-Illinois Steel Corp., Pittsburgh, Pa.	Fe; Cr, 12-14; C, 0.12 max; Mn, 0.50 max; Ni, 0.50 max.	HR, CR, D, P, S, W, B

MAKERS OF CHROMIUM FERRITES

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
1	Allegheny 66	Allegheny Steel Co., Brackenridge, Pa.	Fe; Cr, 15-18; C, 0.12; Mn, 0.50 max.	B, CR, D, HR, P, T, W, B
2	Armco 17	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 16-18; C, 0.12 max.	
3	Avesta 249	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 17; C, 0.10 max.	HR, CR, D, P, S, T, W, B
4	B & W 900	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 17-19; C, 0.10 max, and 0.25 max.	C
5	Bethadur 430	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 17; C, 0.10; Mn, 0.30; Ni, 0.25	HR, D, P, B
6	Carpenter Stainless 6	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 17; C, 0.10	C, HR, CR, D, P, S, T, W, B
7	Chrome Stainless	Warman Steel Casting Co., Huntington Park, Calif.	Fe; Cr, 17	C
8	Colonial 610	Vanadium Alloys Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 17; C, 0.12 max; Ni, 0.80; Mn, 0.35	HR, CR, D, P, S, W, B
9	Colonial 610 F	Vanadium Alloys Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 17; C, 0.12 max; Mn, 0.20; Ni, 0.80	HR, D, P, S, W, B
10	Cooper Alloy 16	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 18-20; C, 0.12; Mn, 0.5	C
11	Duro-Gloss C2	Jessop Steel Co., Washington, Pa.	Fe; Cr, 16-18; C, 0.12 max; Mn, 0.50 max.	HR, CR, P, S, B
12	Enduro AA	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 16-18; C, 0.12 max; Mn, 0.5 max; Si, 0.5 max.	HR, CR, D, P, S, T, W, B
13	Lesco H	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 19; C, 0.10 max; Mn, 0.4; Si, 0.5 max.	HR, CR, D, P, S, W, B
14	Rezistal 17	Crucible Steel Co., New York, N. Y.	Fe; Cr, 15-18; C, 0.12 max.	
15	Rezistal 20	Crucible Steel Co., New York, N. Y.	Fe; Cr, 18-23; C, 0.12 max.	
16	Rustless 17	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 16-18; C, 0.12 max.	HR, D, W, B
17	Silcrome 17	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 16-18; C, 0.10 max; Mn, 0.5 max.	HR, CR, D, P, S, W, B
18	Silcrome RA	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 16-18; C, 0.12 max; Mn, 0.5 max; Cu, 1.0 max.	HR, D, P, S, B, W
19	Sivyer 67	Sivyer Steel Casting Co., Milwaukee, Wis.	Fe; Cr, 16-18; C, 0.20 max.	C
20	Stainless C-2	Vanadium Alloys Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 17; C, 0.12 max.	CR, P, S, W, B
21	Stainless I	Vanadium Alloys Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 13.5; C, 0.12 max; Mn, 0.35	HR, CR, D, P, W, B
22	Stainless M	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 16-18; C, 0.12 max.	
23	Tisco 131	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 16-18; C, 0.10 max; Mn, 0.4-0.6	C
24	Uniloy 1809	Universal Steel Co., Bridgeville, Pa.	Fe; Cr, 16-18; C, 0.07-0.15; Mn, 0.55-0.70	HR, CR, D, P, S, W, B
25	USS 17	Cyclops Steel Co., Titusville, Pa. Carnegie-Illinois Steel Corp., Pittsburgh, Pa.	Fe; Cr, 16-18; C, 0.12 max; Mn, 0.50 max; Ni, 0.50 max; Si, 0.50 max.	HR, CR, D, P, S, T, W, B

** Forms available; B, bars; C, castings; CR, cold rolled; D, drawn; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.

High-Carbon Stainless Steels

THE high carbon, chromium steels containing between 10 and 18 per cent of the alloying element are notable for their great hardness. They are useful for parts of equipment where resistance to abrasion, together with a considerable degree of resistance to atmospheric and chemical attack is desired. Although the steels of this group have unusual tensile and other mechanical properties at normal and elevated temperatures, one of the outstanding features is their resistance to corrosion. The steels attain maximum corrosion resistance when in the hardened condition, and when a clean, smooth surface is exposed. However, they lack ductility and toughness. The process industries are using them for valve parts for high-pressure steam lines, for petroleum refinery and nitric acid plant equipment and for pump plungers for ammonia-synthesis compressors.

The ordinary variety of this steel contains approximately 13 per cent chromium and 0.3 per cent carbon. Those of the variety with a carbon content of about 1 per cent and about 17.25 per cent chromium have about the same resistance to corrosion as the ordinary type but have greater strength and excellent resistance to abrasion.

In addition to these types, there is a variety containing 15 to 18 per cent chromium and 0.50 to 0.70 per cent carbon, and a new one with 16 to 18 per cent chromium, a maximum of 1 per cent carbon and 0.50 per cent molybdenum. This new steel is said to be definitely superior to any of the others.

The principal action of small amounts of nickel on these alloys is to increase the ease with which the steel may be hardened. The particular effect on the mechanical properties of a given chromium steel will depend on whether the latter hardens intensively or not. If the plain chromium steel hardens well, the effect of small nickel additions will be noticeable mainly in tempering operations. In such cases the nickel does not appear to affect appreciably the toughness and ductility of the steel. The advantage of nickel will depend upon the condition of service.

PHYSICAL PROPERTIES OF HIGH-CARBON STAINLESS STEELS

No.	MATERIAL	Specific Gravity	Melting Point °F.	Mean Coeff. Therm. Exp. 32-212° F. x 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
1	Avesta 249H	7.69		0.92	0.06	Heat treated	110	90	25	50		240			
2	Avesta 739	7.73		0.90	0.07	Heat treated	231	154	16	49		460			
3	Avesta 739H	7.72		1.05		Heat treated	165	125	14	38		360			
4	Avesta 739S	7.72		0.91	0.07	Heat treated	216	141	18	51		423			
5	Bethadur 428	7.6	2580-2640	0.57	0.05	Annealed	105	72	23	58	29.5	207	Fair	Yes	W, B
						Tempered	245	198	8	20		495			
6	Bethadur 440	7.6	2580-2640	0.57		Annealed	100	60	23	45		197	Difficult	Yes	
						Tempered	258	195	3	6		495			
7	Carpenter Stainless 2	7.75	2500-2700	0.59-0.7		Hardened	260	225	11	32	28.5	512	Fair	Yes	DD, F, R, W, B
8	Carpenter Stainless 2-B	7.73	2500-2700	0.6-0.68		Hardened					29	625	Fair	Yes	R, B
9	Carpenter Stainless 3	7.688	2500-2700	0.55		Annealed	100	50	22	55	28	190	Good	Yes	F, R, W, B
10	Circle L11	7.6	2600-2700	0.55	0.063	Forged bar	100	75	8	10		200	Good	No	
11	Circle L11-75C	7.6	2600-2700	0.55	0.063		100	75	3	3		220-525	Good	Yes	Cast
12	Circle L13B	7.75		0.55		Forged bar	170-200	120-150	3-10	5-15		400-500	Good	Yes	
13	Circle L14	7.69	2600-2700	0.55		Forged bar	95	68	6	7		195	Good		
14	Colonial 795	7.72	2550-2600			Bar, rolled, treated	210	180	5	9		444	Good	Yes	R, W, B
15	Cooper Alloy 16A	7.6	2700	1.05	0.082	Cast	75	50	20	22		200	Good	Good	
16	Cro Sil														
17	Duraloy B	7.60		0.59		Cast	90	70	15	35		175	Good	No	DD, F, R, W, B
18	Durco D-18					Cast	90	55	5	5		230	Good	No	W
19	Duro-Gloss C-3	7.6				Hot rolled	80	55	35	55		151	Fair	Yes	W, B, DD
20	Empire 46											260		Yes	
21	Hy-Glo	7.7	2724	0.61		Annealed bar	100	70	20	50	30	187	Good	Yes	DD, F, R, W, B
22	Miscrome 1					Cast	90	60	17	20	30	225	Good	Yes	R, W
23	Otisel 2						70-75	38-41	28-33	50-60	28	140-170	Good	Fair	
24	Pennalloy B											550-600	Unmachinable	Yes	
25	Q-Alloy Chrome C-2	7.57	2700	0.6	0.058	Cast	65-75	30-40	25-30	40-50					
26	Regular SS	7.75	2724	0.61		Annealed bar	90	48	28	60	30	179	Good	Yes	DD, F, R, W, B

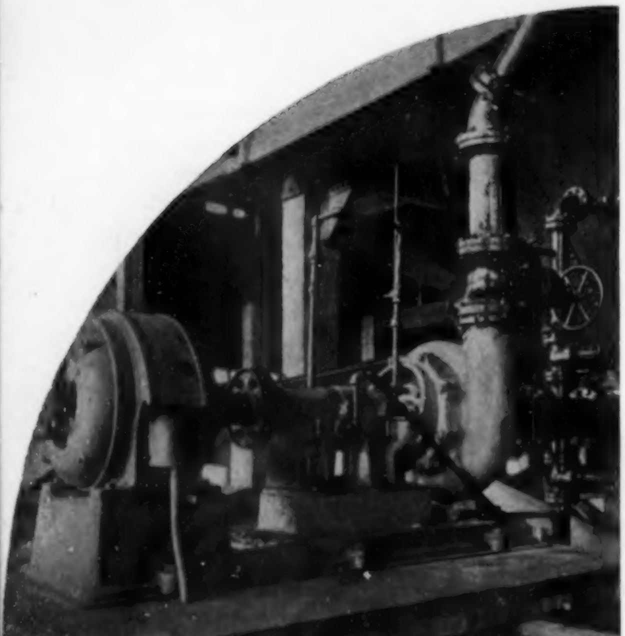
No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
27	Rezistal A					Draw 500° F.	250	220	4	6		524			
						Draw 1400° F	132	103	16	47		290			
28	Rezistal B					Draw 200° F						600			
						Draw 1000° F.						430			
29	Rezistal Stainless BM											R'kw'l C 33-60		Good	
30	Rustless 13HC	7.78		0.57	0.05	Bar, hardened	260	215	3	5	29	550	Fair	Good	W, cold draw
31	Silcrome 21	7.60	2700	0.60	0.050	Annealed	70-80	45-55	25-35	50-60	30	160-190	Fair	Good	W, B
32	Silcrome H-17	7.74	2750	0.60	0.07	Bar	230-250		1-2	2-3	30	560-620	Fair	Good	None
33	Silcrome L-12	7.73	2750	0.61	0.09	Bar	200-220	170-180	5-10	20-25	30	420-480	Fair	Good	None
34	Silcrome M-17	7.74	2750	0.60	0.07	Bar	200-220	170-190	5-10	20-30	30	420-450	Fair	Good	None
35	Sta-Gloss A	7.7				Heat treated	230	220	2.5	2		500	Fair	Yes	W, B
36	Sta-Gloss B	7.7				Heat-treated	280	250				580	Fair	Yes	W, B
37	Stainless A														
38	Stainless A	7.77		0.61	0.033	Hardened	240	200	4	8	30	500	Good		
39	Stainless A	7.74	2625-2650	0.61		Bar, rolled, treated	226	195	9	22		461	Good	Yes	R, W, B
40	Stainless B														
41	Stainless B	7.74	2575-2625	0.61		Bar, rolled, treated	210	175	6	10		440	Good	Yes	F, R, W, B
42	Stainless MG														
43	Uniloy 1435	7.65		0.57	0.059	Annealed	105	75	25	45	28	200	Fair	Fair	F, R, W
						Heat treated	190	150	10	20		450			
44	Uniloy 1860	7.65		0.57	0.059	Heat treated	250	150	Low	Low	28	500	Fair	Good	

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

MAKERS OF HIGH-CARBON STAINLESS STEELS

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
1	Avesta 249 H	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 17.0; C, 0.20-0.25	C, HR, CR, D, P, S, W, B
2	Avesta 739	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 13.5; C, 0.20-0.25	C, HR, CR, D, P, S, W, B
3	Avesta 739 H	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 13.5; C, 0.35	HR, CR, D, P, S, W, B
4	Avesta 739 S	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 14.5; C, 0.15; Mo, 1.0	C, HR, CR, D, P, S, W, B
5	Bethadur 420	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 14; C, 0.35; Ni, 0.25; Mn, 0.30	HR, D, B
6	Bethadur 440	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 17; C, 0.65; Mn, 0.30; Ni, 0.25	
7	Carpenter Stainless 2	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 13; C, 0.30	C, HR, CR, D, P, S, W, B
8	Carpenter Stainless 2-B	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 17; C, 1.00	C, HR, D, W, B
9	Carpenter Stainless 3	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 20; C, 0.30; Cu, 1	C, HR, CR, D, P, S, T, W, B
10	Circle L11	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 19; C, 0.25	
11	Circle L 11-75C	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 18; C, 0.75	C
12	Circle L 13B	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 13; C, 0.25; Ni, 0.5 max.	
13	Circle L 14	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 20; C, 0.30; Cu, 1.0; Ni, 0.5 max.	
14	Colonial 795	Vanadium Alloys Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 17.25; C, 0.95; Ni, 0.80	HR, D, S, W, B
15	Cooper Alloy 16A	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 12-14; C, 0.12-0.35; Mn, 0.50	C
16	Cro Sil	Halcomb Steel Co., Syracuse, N. Y., Crucible Steel Co., New York, N. Y.	Fe; Cr, 10-14; C, 0.20 max; Si, 3	
17	Duraloy B	Duraloy Co., Pittsburgh, Pa.	Fe; Cr, 16-18; C, 0.20	C, HR, CR, D, P, S, T, W, B
18	Durco D-18	Duriron Co., Dayton, Ohio	Fe; Cr, 18; C, 0.30 max.	C
19	Dura-Gloss C-3	Jessop Steel Co., Washington, Pa.	Fe; Cr, 18-23; C, 0.35; Mn, 0.50	HR, CR, P, S, B
20	Empire 46	Empire Steel Castings Co., Reading, Pa.	Fe; Cr, 12-14; C, 0.25 max.; Mn, 0.60-0.80	
21	Hy-Glo	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 17; C, 0.62; Mn, 0.35; Si, 0.5 max.	HR, CR, D, W, B
22	Miscrome 1	Michigan Steel Casting Co., Detroit, Mich.	Fe; Cr, 16; C, 0.25 max.; Mn, 0.75; Ni, 0.80 max.	C
23	Otisel 2	Otis Elevator Co., Buffalo, N. Y.	Fe; Cr, 12-14; C, 0.1-0.2; Mn, 0.6-0.7	C
24	Pennalloy B	Pennsylvania Elec. Steel Casting Co., Hamburg, Pa.	Fe; Cr, 10-12; C, 0.8-1.0	C
25	Q-Alloy Chrome C-2	General Alloys Co., Boston, Mass.	Fe; Cr, 16-20; C, 0.50 max.	C, HR, D, P, S, T, W, B
26	Regular SS	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 13.5; C, 0.35; Mn, 0.35; Si, 0.50 max.	HR, CR, D, W, B
27	Rezistal A	Crucible Steel Co., New York, N. Y.	Fe; Cr, 12-15; C, 0.3-0.4	
28	Rezistal B	Crucible Steel Co., New York, N. Y.	Fe; Cr, 15-18; C, 0.5-0.7	
29	Rezistal Stainless BM	Crucible Steel Co., New York, N. Y.	Fe; Cr, 16-20; C, 1.0 max; Mo, 0.50	
30	Rustless 13 HC	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 13.0-15.0; C, 0.30-0.40	HR, D, W, B
31	Silcrome 21	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 18-23; C, 0.35 max; Mn, 0.50 max; Si, 0.1 max.	HR, D, W, B
32	Silcrome H-17	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 15-18; C, 1.00-1.10; Mn, 0.50 max.	HR, D, B
33	Silcrome L-12	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 12-15; C, 0.30-0.40; Mn, 0.50 max.	HR, D, W, B
34	Silcrome M-17	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 15-18; C, 0.60-0.70; Mn, 0.50 max.	HR, D, W, B
35	Sta-Gloss A	Jessop Steel Co., Washington, Pa.	Fe; Cr, 12-15; C, 0.30-0.40; Mn, 0.35-0.45	HR, CR, P, S, B
36	Sta-Gloss B	Jessop Steel Co., Washington, Pa.	Fe; Cr, 15-18; C, 0.55-0.65; Mn, 0.50	HR, CR, P, S, B
37	Stainless A	Henry Disston & Sons, Inc., Tacony, Philadelphia, Pa.	Fe; Cr, 13.5; C, 0.30; Mn, 0.3	HR, P, S, B
38	Stainless A	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 12-15; C, over 0.12	HR, CR, D, S, W, B
39	Stainless A	Vanadium Alloys Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 13.5; C, 0.35; Mn, 0.35	HR, D, P, S, W, B
40	Stainless B	Henry Disston & Sons, Inc., Tacony, Philadelphia, Pa.	Fe; Cr, 16.5; C, 0.55; Mn, 0.3	HR, P, S, B
41	Stainless B	Vanadium Alloys Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 16.5; C, 0.65; Mn, 0.35	HR, CR, D, P, W, B
42	Stainless MG	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 18-23; C, 0.35 max.	B
43	Uniloy 1435	Universal Steel Co., Bridgeville, Pa.	Fe; Cr, 11-14; C, 0.3-0.4; Mn, 0.3-0.5	HR, CR, D, P, S, W, B
44	Uniloy 1860	Universal Steel Co., Bridgeville, Pa.	Fe; Cr, 16-18; C, 0.6-0.8; Mn, 0.3-0.5	HR, CR, D, P, S, W, B

** Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.



25-30 Chromium Irons

HIGH CHROMIUM imparts to alloys remarkable resistance to oxidation at high temperatures and to oxidizing liquids and gases. Alloys of 25 to 30 per cent chromium are indefinitely resistant to exposure at high temperatures under oxidizing conditions, to sulphur, and to nitrogen oxides. The protection is due to an oxide coating that is formed. These remarkable characteristics are somewhat independent of the amount of carbon present in the alloy.

Prolonged holding of the alloys between 750 and 1,025 deg. F. will cause deterioration in physical properties resulting in embrittlement and in some cases in loss of corrosion resistance. This susceptibility to embrittlement and corrosion has operated to restrict the use of these materials for some purposes, especially for high-pressure equipment. But the embrittlement may be easily removed by annealing above 1,300 deg. F.

The wrought alloys may be made more forgeable and ductile by additions of columbium or titanium, while nitrogen improves the strength and toughness of castings without greatly affecting the hardness or machinability. The tensile strength of both forgings and castings are sufficiently high to permit use in designs sustaining fairly high unit loads, the ductility in the forged material is moderately high but in the castings it is low.

Carbon monoxide and reducing flue gases are without effect until high temperatures are attained; however, above 2,100 to 2,200 deg. F. such reducing atmospheres have a deteriorating effect on the alloys. As long as the atmosphere is oxidizing, the alloys seem to be safe nearly up to their melting points. Sulphur and sulphur gases up to 1,800 deg. F. do not attack these alloys that are substantially free from other metals. Nitric acid is without effect when the alloys are in the proper state with regard to heat treatment, while hydrochloric acid readily corrodes them. Mixtures of the two acids may or may not prove harmful, depending on the balance between film formation and destruction. Plants producing nitric acid or nitrocellulose are users of large amounts of these alloys because of the greater dependability in diversified work. The same may be said of other chemical producers. In cases where dilute sulphuric acid contains sufficient ferric sulphate to maintain oxidizing conditions, these alloys are useable. They are also in use for tank cars for shipping concentrated sulphuric acid where traces of iron in the acid would cause an objectionable discoloration.

The low carbon rolled alloys are used for recuperators, heat exchangers, baffles, and structural parts in Cottrell precipitators. Other uses for the alloys of this type are char retorts, mufflers and muffler linings, blades in cement mills. Chrome irons stand up very well in coke crushing, screening and conveying equipment.

The low carbon castings find their greatest use for disks, shafts, conveyor chains and other parts of furnaces, for burner points, racks and other parts of enameling furnaces. Castings with medium carbon content combine unusual heat resistance with excellent resistance to abrasion.

Illustration shows a Duraloy sand pump.

Resistance to Mixed Acids*

(Boiling 3.3% HNO_3, 42% H_2SO_4, 24% H_2O)

Alloys

	A	B	C	D	E
Chromium...	34.40%	34.00	32.84	32.72	31.67
Carbon......	0.124%	1.04	1.40	2.21	3.10

Loss in Weight

(In grams per square centimeter per hour)

	A	B	C	D	E
1st hr.....	0.00045	0.00052	0.00091	0.0049	0.00735
2nd hr....	0.00043	0.000625	0.00136	0.0038	0.0056
3rd hr....	0.000423	0.000545	0.00142	0.00475	0.0060

* W. F. Furman, High Chromium Iron Alloys for Castings, *Meta & Alloys*, Oct. and Nov., 1933.

Corrosion Resistance of the 25-30 Per Cent Chromium Irons

Ammonium Hydroxide

(Cr. 34%, Si. 0.67%, C. 0.48%)

	Temperature Deg. F.	Duration Hr.	In. Penetration per Mo. X 100
20% Ammonium Hydroxide..	140	24	None
20% Ammonium Hydroxide..	Room	48	None
20% Ammonium Hydroxide..	boiling	½	None

These and other corrosion data from W. F. Furman

Nitric Acid

(Cr. 34%, Si. 0.67%, C. 0.48%)

	Temperature Deg. F.	Duration Hr.	In. Penetration per Mo. X 100
70% Nitric Acid............	194	72	0.029
70% Nitric Acid............	248	72	0.024
70% Nitric Acid............	Room	108	None
50% Nitric Acid............	194	72	0.0094
25% Nitric Acid............	194	72	0.0059
10% Nitric Acid............	194	72	0.0019
1% Nitric Acid............	194	72	0.0027

Resistance to the Corrosion of Chemicals

(Cr., 34%; Si., 0.67%, C., 0.48%)

Phosphoric Acid

Solution	Temperature, Deg. F.	Duration, Hr.	% Loss in Weight
85% Phosphoric Acid	Room	24	Nil
85% Phosphoric Acid	212	24	0.13
50% Phosphoric Acid	Room	24	Nil
50% Phosphoric Acid	212	12	Nil

Citric Acid

Solution	Temperature Deg. F.	Duration Hr.	In. Penetration per Mo. X 100
85% Citric Acid	Room	48	None
85% Citric Acid	185	48	None
1% Citric Acid	Room	48	None
1% Citric Acid	185	48	None

Sodium Hydroxide

Solution	Temperature Deg. F.	Duration Hr.	In. Penetration per Mo. X 100
25% Sodium Hydroxide	194	72	None
10% Sodium Hydroxide	194	72	0.0015
1% Sodium Hydroxide	194	72	0.0030

Physical Properties of 25 to 30 Chromium Irons

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10^5	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
1	**Allegheny 55**	7.6	2695–2715	0.56	0.059	Annealed bar	75	45	35	65	28	160	Fair		B, F, R, W
2	**Armco 27**						80	50	23						
3	**Avesta 831**	7.66		0.95	0.06	Air cooled from 1472°F	70	51	35	60		180			
4	**B & W 950**	7.6		0.55	0.05	Annealed	75	50	20	50	29	160	Excel.	No	B, F, R, W
						As cast	50	30	1	1					
5	**Bethadur 446**	7.59	2740–2800	0.56		Annealed	90	50	18	37		187	Fair	No	
6	**Circle L15**	7.50	2600–2675	0.56	0.064		60	35	3	4		190	Good		
7	**Cooper Alloy 19**	7.6	2700	0.59	0.082	Cast	50	35	2	3		170	Good	Yes	
8	**Croloy 27**	7.6		0.518	0.059	Annealed	75–90	45–60	15–30		28–30	160–195	Fair	Fair	F, W
9	**Duraloy A**	7.60	2650	0.67		Rolled	80–90	60–70	10–27	15–45			Good	Good	DD, R, W
						Cast	40–50	30–40	1	0– 2					
10	**Durco D-28**					Cast	55	40				230	Good	No	W
11	**Duro-Gloss C4**	7.5				Hot rolled	90	55	25	55		171	Fair	Yes	DD, W, B
12	**Empire 21**											130			
13	**Enduro HC**	7.60	2775	0.56	0.045	Annealed sheet	80	50	24		28	179	Fair	Fair	F, R
14	**Lesco HH**	7.6	2804	0.57		Annealed bar	70	45	30	60		163	Fair		W, B
15	**Midvaloy 26-02**	7.6				Cast	75–100	60–80	20–30	40–60		165–200	Fair		R, W, B
16	**Miscrome 3**						60						Good	No	
17	**Otisel 5**						50–60	40–55	2–5	2–5		160–190	Good	Slight	
18	**Pyrocast**	7.55	2600–2650	0.57	0.06	Cast	65–70	None	0	0		300–600	Machinable	Yes	Casting
19	**Q-Alloy C-1**	7.75	2700	0.59	0.05	Annealed casting	75–85	50–60	20–30	30–40			Machinable	Good	R W
20	**Rezistal 27**	7.65			0.059	Annealed	80–90	55–65	20–30	40–50		160–200	Machinable		R
21	**Silcrome 28**	7.60	2700	0.60	0.05	Annealed bar	75–95	45–60	20–30	50–60	29	150–200	Fair	Good	R, W, B
22	**Tisco 130**						40–60	30–40	0– 3	0– 5			Good	No	
23	**Uniloy 2825**	7.65		0.59	0.059	Hot rolled	75–100	50–70	20	50	28–30	160–200	Fair	No	R
24	**USS 27**	7.5	2710–2750	0.59	0.05	Annealed	75–95	50–65	20–30	50–60		160–190		Yes	F, R, W

* Methods of fabribation: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

Makers of 25 to 30 Chromium Irons

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available **
1	**Allegheny 55**	Allegheny Steel Co., Brackenridge, Pa.	Fe; Cr, 26–30; C, 0.25 max; Ni, 0.60 max; Mn, 1.0 max.	CR, HR, B, D, S, P, T, W
2	**Armco 27**	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 23–30; C, 0.35 max.	
3	**Avesta 831**	A. Johnson & Co., Inc., New York, N. Y.	Fe; Cr, 24; C, 0.20	HR, P, S, T, B
4	**B & W 950**	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 26–30; C, 0.10 max and 0.25 max.	C
5	**Bethadur 446**	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 28; C, 0.30; Mn, 0.30; Ni, 0.25	HR, B
6	**Circle L 15**	Lebanon Steel Fdry, Lebanon, Pa.	Fe; Cr, 28.5; Ni, 0.50 max; C, 0.30	
7	**Cooper Alloy 19**	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 28; C, 0.30; Ni, 0.5–2; Mn, 0.50	C
8	**Croloy 27**	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 25–30; C, 0.25 max; Mn, 1.00 max; Si, 0.50 max.	C, CR, HR, T
9	**Duraloy A**	Duraloy Co., Pittsburgh, Pa.	Fe; Cr, 27–30; Mn, 0.60; C, 0.25	C, HR, CR, P, S, T, W, B
10	**Durco D-28**	Duriron Co., Dayton, Ohio	Fe; Cr, 28; C, 0.25–0.50	C
11	**Duro-Gloss C4**	Jessop Steel Co., Washington, Pa.	Fe; Cr, 23–30; C, 0.35 max; Mn, 0.50 max.	HR, CR, P, S, B
12	**Empire 21**	Empire Steel Castings, Inc., Reading, Pa.	Fe; Cr, 26–30; C, 0.15–0.60; Ni, 3.0 max.	C
13	**Enduro HC**	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 23–30; C, 0.20 max; Mn, 0.50 max; Si, 0.50 max; P; S	P, S, B
14	**Lesco HH**	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 27; C, 0.20 max; Mn, 0.4; Si, 0.5 max.	B, HR, P, S
15	**Midvaloy 26-02**	Midvale Co., Philadelphia, Pa.	Fe; Cr, 26.5; C, 0.25; Ni, 1.5	C, HR, B
16	**Miscrome 3**	Michigan Steel Casting Co., Detroit, Mich.	Fe; Cr, 28; C, 0.30; Ni, 1.00 max; Mn, 0.60	C
17	**Otisel 5**	Otis Elevator Co., Buffalo, N. Y.	Fe; Cr, 26–30; C, 0.15–0.20; Mn, 0.6–0.7	C
18	**Pyrocast**	Pacific Foundry Co., San Francisco, Calif.	Fe; Cr, 25; C, 1.75; Ni, 3.00; Mo, 2.00 max.	C
19	**Q-Alloy C-1**	General Alloys Co., Boston, Mass.	Fe; Cr, 26–30; C, 0.60 max; Ni, 3.0 max.	C, HR, D, S, T, W, B
20	**Rezistal 27**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 23–30; C, 0.35 max.	
21	**Silcrome 28**	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 23–30; C, 0.25 max; Mn, 0.75 max.	HR, D, W, B
22	**Tisco 130**	Taylor Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 26–30; C, 0.10; Mn, 0.40–0.60	C
23	**Uniloy 2825**	Universal Steel Co., Bridgeville, Pa.	Fe; Cr, 25–30; C, 0.10–0.30; Mn, 0.25–0.70	HR, CR, D, P, S, W, B
		Cyclops Steel Co., Titusville, Pa.		
24	USS 27	Carnegie-Illinois Steel Corp., Pittsburgh, Pa.	Fe; Cr, 25–30; C, 0.10 max; Mn, 0.50 max.	HR, CR, D, P, S, T, W, B

** Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.

18-8 Cr-Ni Alloys

CHROME-NICKEL steel alloys of the class known as 18-8 are among the best materials available for general utility purposes. The term 18-8 is used to cover a large group of alloys, such as 16-6 or 28-15 chromium and nickel, with or without the addition of small quantities of other alloying metals. Physical properties are little affected by variations in the nickel and chromium content, but such variations have marked effects on the corrosion resistance and stability of the alloy when heated for short periods of time at certain critical temperatures.

When the total chromium and nickel is increased, the alloy becomes more resistant to many chemicals, and for severe service the total of these elements should be at least 26 per cent. Increasing carbon content decreases corrosion resistance, as does the carbide segregation which presumably takes place when the alloys are held for a sufficiently long time between 800 and 1,500 deg. F. When segregation takes place the alloys become susceptible to intergranular corrosion or embrittlement in certain strong chemicals. High carbon steels require less time for this change to take place, but various modifications in composition greatly reduce the susceptibility.

Addition of titanium decreases the general corrosion resistance slightly but is said, under certain conditions, to yield immunity to intergranular corrosion. Silicon makes a slightly harder steel, improves welding qualities and strongly inhibits susceptibility to intergranular corrosion, when present in sufficient quantity. It increases the resistance to dilute HCl and H_2SO_4 at normal temperatures, but increases the corrosion by hot concentrated HNO_3. Tungsten both increases intergranular corrosion resistance and improves high-temperature strength. Molybdenum, which is probably the most useful addition agent, improves both general corrosion resistance and high temperature strength, while columbium, the newest of the addition agents, lessens susceptibility to intergranular corrosion and tends to correct the loss of toughness which normally results in low carbon steels from exposure to temperature of 1,200-1,500 deg. F.

A beneficial effect in avoiding grain growth at high temperatures is obtained in certain alloys by a nitrogen content in the order of 0.20-0.30 per cent. A new alloy, an 18-8 containing usually 2.9 per cent copper and 4-6 per cent of manganese, does not require as high a final heat treatment in developing full corrosion resistance. Another new alloy has most of the nickel replaced by manganese or manganese and copper.

How 18-8 Alloys Are Used

Alloys of this class are so widely used that no reasonably complete listing of applications is possible here. However, the following summary gives a fair idea of their field of use. Manufacturers' catalogs may be consulted for more specific information, while corrosion tests should be conducted before applications are finally undertaken.

Almost every sort of equipment has been fabricated from these alloys, including such items as piping, kettles, stills, dryers, valves, condensers, towers, evaporators, extractors and digesters. In general, the alloys are not satisfactorily resistant to certain classes of corrosive agents, including the free halogens, the halogen acids and certain halogen compounds including aluminum chloride and fluoride, silver, stannic and sulphur chlorides, and boiling ferric chloride solution. They are not suitable for very concentrated acetic acid and acetic acid vapors at high temperatures, nor for concentrated nitric acid nor most concentrations of sulphuric acid, at high temperatures.

However, for many classes of materials, their resistance ranges from fairly good to excellent. Among these may be mentioned most concentrations and temperatures of organic, nitric, phosphoric and sulphurous acids; the alums, alcohols and ammonia liquor; ammonium, barium, calcium, copper, magnesium, nickel, potassium, sodium, and zinc salts; hydrocarbons and oils of all sorts; nitrates, peroxides, sulphates and sulphides; beverages, juices, sea water and soap. The addition of molybdenum, as noted above, improves the resistance slightly in a good many cases. It gives marked improvement with a few chemicals including calcium bisulphite at high temperature and pressure; and concentrated, boiling solutions of citric, oxalic and phosphoric acids.

PHYSICAL PROPERTIES OF 18-8 CHROME-NICKEL ALLOYS

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp. 32-212° F. x 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
1	Allegheny Metal	7.92	2606-2679	0.96	0.069	Annealed bar	90	45	60	70	28.6	135	Fair	Yes	DD, F, R, W, B
2	Allegheny 44		2552-2507	0.90	0.039	Annealed bar	90	45	60	70	29.5	135	Fair	Yes	DD, F, R, W, B
3	Amsco F-8	7.9	2460-2600	0.90	0.06	Cast	70-90	25-45	40-70	40-70		150-180	Good	Yes	W
4	Amsco F-10	7.9- 8.1	2460-2570	0.7- 0.9	0.03- 0.04	Cast	80-100	40-55	15-35	12-32		160-190	Fair	Yes	W
5	Armco 16-6						95	45	55						DD, W, R
6	Armco 17-7						90	45	55						DD, W, R
7	Armco 18-8	7.93		0.96	0.05		80	35	60-70		29				DD, W, R
8	Armco 18-8	7.93		0.96	0.05		85	45	60		29				DD, W, R
9	Armco 19-9						80	35	60-70		29				DD, W, R

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10^6	Therm. Cond. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
10	Armco 19-9	7.93		0.96	0.05		85	45	60		29				DD, W, R
11	Armco 25-12						95	45	45						
12	Armstrong Metal					Hot rolled	90		42	66		170	Good		DD, F, R, W
13	B & W 600	7.90		0.90	0.039	Annealed	80	35	60	70	29	140	Fair	No	DD, F, R, W, B
14	B & W 640	7.90		0.90	0.039	Annealed	80	35	60	70	29	140	Fair	No	DD, F, R, W, B
15	B & W 650	7.90		0.90	0.039	Annealed	90	40	45	55	29	160	Fair	No	DD, F, R, W, B
16	B & W 661	7.90		0.90	0.039	Cast	75	40	25	25	29		Fair	No	W, B
17	B & W 800	7.90		0.90	0.035								Poor	Yes	W, B
18	B & W 1500	7.9		0.90	0.038								Fair	No	W, B
19	Bethadur 302	7.90	2600–2750	0.92	0.042	Cold drawn	150	130	30	55		280			
						Annealed	90	42	42	62	29	162	Fair	No	DD, F, R, W, B
20	Bethalon 303	7.90	2600–2750	0.92	0.042	Annealed	90	40	35	50	29	152	Excel.	No	W, B
21	Calite B-28	7.65	2750			Cast	75–85	35–40	25–30	20–25		200	Fair	Fair	
22	Calite BL	7.65	2750			Cast	75–80	35–40	30	30		200	Fair	Fair	
23	Calite E	7.86	2750			Hot rolled	111	74	43	66		223	Good		
24	Calite E-28	7.86	2750			Hot rolled	131	107	31	60		262	Good	No	
25	Carpenter Stainless 4	7.93	2500–2650	0.88	0.052	Annealed	89	35	63	73	28	140	Poor	Yes	DD, F, R, W, B
26	Cimet	8.00	2516	0.93		Cast	62						Fair	No	
27	Circle L 22	7.80	2575–2675	0.89	0.063		70	30	50	50		135	Fair	Slight	
28	Circle L 23	7.80	2550–2650	0.89	0.063	Hot rolled	75	35	50	50		150	Fair	Slight	
29	Circle L 30	7.9	2625–2725	0.78	0.025		80	40	30	30		160	Good	No	
30	Circle L 31	7.9	2625–2725	0.78	0.025		83	47	15	10		155	Fair	Slight	
31	Cooper Alloy 17	7.9	2700	0.95	0.069	Cast	84	42	47	42		160	Good	No	
32	Cooper Alloy 22	7.6	2700	0.92	0.142	Cast	70	55	15	12		200	Good	Yes	
33	Croloy 16-13-3	8.03	2550	0.90	0.05	Annealed	90	47.5	48.5		28	155	Machinable	Fair	F, W
34	Croloy KA2	7.90	2550	0.92	0.052	Annealed	90	35	65		28–30	145	Machinable	Fair	F, W
35	Defistain	7.93		0.95	0.050	Bar	90	35	60	70	26	150	Fair	No	R, W, B, cold dr.
36	Defistain-Machining	7.93		0.95	0.050	Bar	90	35	55	60	26	160	Excel.	No	R, W, B
37	Duraloy 18-8	7.86	2600	0.998		Cast	80	45	50	55	28		Fair	No	DD, R, W
38	Duraloy N	7.88	2550–2650	0.89		Cast	85	55	30	30			Fair	Fair	DD, R, W
39	Durco 26-12					Cast	70	31	30	30		200	Good	No	W
40	Durco KA2S	7.89	2650	0.94	0.05	Cast	80–90	30–35	43–48	43–48		125	Good	No	W
41	Durco KA2SMo	7.89	2650	1.06	0.05	Cast	85–95	35–40	40–45	45–50		140	Good	No	W
42	Empire 39	7.85	2650	0.94	0.03–0.116	Cast	80–100	65–75	5–15	10–20	28	140	Good		
43	Empire 40								35	55		140			
44	Enduro 16-6	7.8	2550			Annealed	90	40	40		29	179	Fair	Good	DD, F, R, W
45	Enduro 16-6X	7.8	2550			Annealed	85	35	45		29	179	Fair	Good	DD, F, R, W
46	Enduro 18-8	7.80	2560	0.90	0.035	Annealed sheet	85	35	55		29	179	Fair	Yes	DD, F, R, W
47	Enduro 18-8B	7.80	2550		0.035	Annealed strip	90	40	45		29	179	Fair	Good	DD, F, R, W
48	Enduro 18-8-SMo	7.80	2550	0.90	0.035	Annealed sheet	90	40	50		29	179	Fair	Yes	DD, F, R, W
49	Enduro HCN	7.80	2575	0.90	0.03	Annealed sheet	90	40	50		29	179	Fair	Yes	DD, F, R, W
50	Fahrite N-2	7.9					65	35	30	30					
51	Fahrite N-3	7.90				Cast	70	32	15	20		210	Fair		W
52	Heat Resisting 5	7.75				Hot rolled	100	45	60	68		163	Fair	Yes	DD, W, B
53	Heat Resisting 5B	7.75				Hot rolled	110	45	60	68		163	Fair	Yes	DD, W, B
54	Hi Gloss	7.8				Hot rolled	90	45	60	70		150	Fair	Yes	DD, W, B
55	Hi Gloss FM	7.8				Hot rolled	90	45	60	70		150	Good	Yes	DD, W, B
56	IngAclad 306	7.8	2550–2590†	0.96†	0.038†		62–65	53	43	53		150†		Fair	DD, F, R, W
57	IngAclad 316	7.8	2550–2590†	0.93†	0.038†		65	53	43	53		150†		Fair	DD, F, R, W
58	Lesco 18-8	7.88	2550	0.89	0.046	Annealed bar	87	33	58	70	28.5	143	Fair		DD, F, R, W, B
59	Lesco 18-8S	7.88	2650	0.89	0.046	Annealed bar	87	33	58	70	28.5	143	Fair		DD, F, R, W
60	Lesco 21-12	7.86		0.89	0.040	Annealed bar	90	40	45	62		156	Fair		DD, F, R, W, B
61	Midvaloy 18-8	7.86	2550	0.88	0.05	Wrought	75–145	30–110	20–60	30–70		130–280	Fair		DD, F, R, W, B
						Cast	70–85	35–45	35–50	30–60		130–150			
62	Midvaloy 25-10	7.86		0.90		Forged	75–115	45–65	25–45	30–50		150–240	Fair		F, R, W, B
63	Milwaloy 26														
64	Milwaloy 38														
65	Misco 18-8					Cast	70	35	40	40		200	Fair	Yes	
66	Misco B					Cast	70	35	30	30	23.6	200	Fair		R, W
67	Misco C			0.756		Cast	85	45	20	20	21.9	225	Fair		R, W
68	Nirosta	7.86	2642	0.88	0.052	Wrought	85–90	40	55–60	65			Fair	No	DD, F, R, W, B
69	Nirosta 17-7	7.93													
70	Nirosta 19-9	7.93													
71	Nirosta FC	7.93											Excel.		
72	Nirosta KA2	7.93	2700	1.10	0.039	Austenitic	85–95	30–35	55–60	70–75	29	145–160			
73	Nirosta KA2S	7.93													
74	Nirosta Calmar KA2	7.9		0.89	0.035	Cast	70	30	50		27–28	180	Fair	Yes	
75	Otisel 1						74–80	37–41	55–60	60–70	28.6	140–155	Good	Slight	
76	Otisel 4		2550–2600				78–85	42–48	50–55	55–60	29.5	140–170	Good	Slight	
77	Q-Alloy CN-1	7.8	2500	0.83	0.04	Cast	85–90	40–45	35–45	45–50		175	Good		R, W
78	Q-Alloy CN1-H														
79	Q-Alloy CN1-Mo														
80	Q-Alloy CN-2	7.9	2600	0.96	0.039	Cast	75–80	35–40	35–45	45–50		175	Good		DD, F, R, W, B

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.
† Refers to stainless surface which comprises approximately 20 per cent of the total sheet or plate thickness.

PHYSICAL PROPERTIES OF 18-8 CHROME-NICKEL ALLOYS (Continued)

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10⁶	Therm. Cond. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point, 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10⁻⁶	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
81	Rezistal 2C	7.77		0.89		Annealed	90-100	40-50	50-60	50-70	28-30	140-180	Fair		R, W
82	Rezistal 3			0.89	0.039	Annealed	95-105	40-50	40	50	28-30	170-200	Fair		R, W
83	Rezistal KA2	7.94	2550	0.89	0.052	Annealed	85-95	30-40	55-60	65-75	28-30	130-170	Fair		R, W
84	Rezistal KA2SMo	7.91		0.89	0.052	Annealed	90-100	40-50	50-60	60-75	28-30	170-200	Fair		R, W
85	Rezistal KA2ST	7.94	2550	0.89	0.052	Annealed	85-95	30-40	55-60	65-75	28-30	130-170	Fair		R, W
86	Rustless 18-8-3 Mo	7.93		0.94	0.050	Bar	100	50	48	67	26	160	Fair	No	F, W, B
87	Rustless 25-12	7.8		1.02	0.074	Bar	90	60	45	60	26	160	Fair	No	R, W, B
88	Silcrome 25-12	7.64	2700	0.83	0.05	Annealed bar	85-95	45-60	35-50	40-55		150-190	Fair, tough	Good	R, W, B
89	Silcrome KA2	7.86	2560	0.89	0.053	Annealed bar	85-95	30-40	55-60	50-75	29	135-170	Fair	Good	DD, F, R, W, B
90	Silcrome KA2-C	8.00	2600	0.86	0.040	Annealed bar	80-90	35-45	50-60	55-70	29	140-190	Fair	Good	DD, F, R, W, B
91	Silcrome KA2-EZ	7.86	2560	0.89	0.053	Annealed bar	85-95	35-45	55-60	50-70	28.3	160-190	Good	Good	Bar stock only
92	Silcrome KA2-S	7.86	2560	0.89	0.053	Annealed bar	85-95	30-40	55-60	50-75	29	135-150	Fair	Good	DD, F. R, W, B
93	Silcrome KA2-SM	8.00	2600	0.83	0.052	Annealed bar	80-90	35-50	50-65	55-70	29	140-200	Fair, tough	Good	DD, F, R, W, B
94	Silcrome KA2-T	8.00	2600	0.86	0.040	Annealed bar	80-90	40-50	50-60	50-60	29	140-190	Fair	Good	DD, F, R, W, B
95	Sivyer 60	7.85	2600-2650	0.90		Cast	70-80	30-40	50-60	50-70		135-150	Good		B, W
96	Sivyer 62	7.80	2600-2700	0.90		Cast	75-85	30-40	35-45	35-50			Fair		
97	Stainless N	7.82	2600	0.89	0.035	Bar, rolled and annealed	92	42	58	70			Poor	No	DD, F, R, W, B
98	Stainless U	7.83	2600-2625	0.89	0.035	Bar, rolled and annealed	87	41	52	72		150	Fair	No	DD, F, R, W, B
99	Tisco 28-11						75-85	45-50	12-18	8-12		150-160	Fair	No	
100	Tisco KA2						70-75	30-35	50-60	45-60		130-150	Poor	No	
101	Tisco KA2Mo						70-75	30-35	50-60	45-60		130-150	Poor	No	
102	Tisco KA2S						65-70	25-30	50-60	45-60		130-150	Poor	No	
103	Tisco KA2S Mo						65-70	25-30	50-60	45-60		130-150	Poor	No	
104	Uniloy 18-8	7.86		0.96	0.039	Annealed	85	40	50	60		150			
						H or C rolled	200	150			29	300	Fair	No	DD, F, R, W
105	Uniloy 24-11	7.80		0.83	0.030	Annealed	90-110	40-60	35	45	28	150-200	Poor	No	DD, F, R, W
106	USS 18-8	7.9	2550-2590	0.96	0.039	Annealed	80-95	30-45	55-70	65-75	29	135-185	Fair to good	Yes	DD, F, R, W
107	USS 25-12	7.8	2530-2570	0.83	0.03-0.04	Annealed	90-110	40-60	30-45	45-60		150-185	Fair	Yes	DD, F, R, W
108	48 Alloy	7.75		0.83	0.030	Cast	75	55	1	1		210	Fair		
109	49 Alloy														
110	63 Alloy														
111	100 Alloy	7.87	2400-2475	0.90		Cast	65	45	3.5	3			Fair		DD, W

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

MANUFACTURERS OF 18-8 CHROME-NICKEL ALLOYS

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Allegheny Metal	Allegheny Steel Co., Brackenridge, Pa.	Fe; Cr, 16-20; Ni, 7-10; C, 0.12 max; Mn, 0.50 max.	HR, CR, D, P, S, W, B, T
2	Allegheny 44	Allegheny Steel Co., Brackenridge, Pa.	Fe; Cr, 20-30; Ni, 10-20; C, 0.20 max; Mn, 1.0	C, HR, CR, D, P, S, W, B
3	Amsco F-8	Amer. Manganese Steel Co., Chicago Hghts., Ill.	Fe; Cr, 20-22; Ni, 8-10; C, 0.20 max; Mn, 1.0 max; Si, 1.5 max.	C
4	Amsco F-10	Amer. Manganese Steel Co., Chicago Hghts., Ill.	Fe; Cr, 26-28; Ni, 10-13; C, 0.35 max; Mn, 1.0 max; Si, 1.5 max.	C
5	Armco 16-6	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 15-17; Ni, 5-7; C, 0.12-0.2	
6	Armco 17-7	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 16-18; Ni, 7-8.5; C, 0.1-0.2	
7	Armco 18-8	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 17-19; Ni, 7-9.5; C, 0.08 max.	
8	Armco 18-8	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 17-19; Ni, 7-9.5; C, 0.08-0.12	
9	Armco 19-9	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 18-20; Ni, 8-10; C, 0.08 max.	
10	Armco 19-9	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 18-20; Ni, 8-10; C, 0.08-0.12;	
11	Armco 25-12	Amer. Rolling Mill Co., Middletown, Ohio	Fe; Cr, 22-26; Ni, 12-14; C, 0.20 max.	
12	Armstrong Metal	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 17.5; Ni, 8; C, 0.10; Mn, 4-6; Cu, 2.9	
13	B & W 600	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 17-19; Ni, 7.5-10.5; C, 0.08 max and 0.16 max.	C, W
14	B & W 640	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 19-22; Ni, 8.5-9.5; C, 0.08 max and 0.16 max; Mo, 2.5-3.5	C
15	B & W 650	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 22-25; Ni, 10-13; C, 0.10 max and 0.16 max.	C
16	B & W 661	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 22-25; Ni, 10-13; C, 0.3-0.6; Si, 2.0-2.5	C
17	B & W 800	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 24-26; Ni, 10-12; C, 1.0-1.5; Si, 1.0-2.0	C
18	B & W 1500	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 26-28; Ni, 7.5-9.5; C, 0.35 max; Si, 1.5-2.5	C
19	Bethadur 302	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 18; Ni, 8; C, 0.10; Mn, 0.30	HR, D, P, B
20	Bethalon 303	Bethlehem Steel Co., Bethlehem, Pa.	Fe; Cr, 18; Ni, 8; C, 0.10; Mn, 0.30; S, 0.3-0.5	HR, D, B
21	Calite B-28	Calorizing Co., Pittsburgh, Pa.	Fe; Cr, 25; Ni, 10	C
22	Calite BL	Calorizing Co., Pittsburgh, Pa.	Fe; Cr, 21; Ni, 9	C
23	Calite E	Calorizing Co., Pittsburgh, Pa.	Fe; Cr, 18; Ni, 8	HR, CR, P, S, W, B
24	Calite E-28	Calorizing Co., Pittsburgh, Pa.	Fe; Cr, 25; Ni, 10	HR, CR, P, S, W, B
25	Carpenter Stainless 4†	Carpenter Steel Co., Reading, Pa.	Fe; Cr, 18; Ni, 9; C, 0.10	C, HR, CR, D, P, S, T, W, B
26	Cimet	Driver-Harris Co., Harrison, N. J.	Fe; Cr, 23-28; Ni, 10-13	C
27	Circle L 22	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 19; Ni, 9; C, 0.07 max.	
28	Circle L 23	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 19; Ni, 9; C, 0.15	
29	Circle L 30	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 24; Ni, 10; C, 0.15	
30	Circle L 31	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 28; Ni, 11; C, 0.25	
31	Cooper Alloy 17	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 18; Ni, 8; C, 0.07-0.20; Mn, 0.50	C
32	Cooper Alloy 22	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 26-28; Ni, 8-10; C, 0.35; Mn, 0.50	C
33	Croloy 16-13-3	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 16; Ni, 13; C, 0.15 max; Mn, 1.00 max; Mo, 3	C, HR, CR, T
34	Croloy KA-2	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 18; Ni, 9; C, 0.07 or 0.15 max; Si, 0.45	C, HR, CR, T

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available*
35	**Defistain**	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 17–19; Ni, 7–10; C, 0.12 max.	HR, D, W, B
36	**Defistain-Machining**	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 17–19; Ni, 7–10; C, 0.15 max; S, 0.50 max.	HR, D, W, B
37	**Duraloy 18–8**	Duraloy Co., Pittsburgh, Pa.	Fe; Cr, 16–18; Ni, 8–10; C, 0.15	C, HR, CR, D, P, T, W, B
38	**Duraloy N**	Duraloy Co., Pittsburgh, Pa.	Fe; Cr, 24–28; Ni, 10–12; C, 0.20	C, HR, CR, P, S, W, B
39	**Durco 26–12**	Duriron Co., Dayton, Ohio	Fe; Cr, 26; Ni, 12; C, 0.25 max.	C
40	**Durco KA2S**	Duriron Co., Dayton, Ohio	Fe; Cr, 18; Ni, 8; C, 0.07 max.	C
41	**Durco KA2SMo**	Duriron Co., Dayton, Ohio	Fe; Cr, 18; Ni, 8; C, 0.07 max; Mo, 3	C
42	**Empire 39**	Empire Steel Castings, Inc., Reading, Pa.	Fe; Cr, 17–21; Ni, 7–9; C, over 0.15	C
43	**Empire 40**	Empire Steel Castings, Inc., Reading, Pa.	Fe; Cr, 18–22; Ni, 7–9; C, over 0.15	C
44	**Endure 16–6**	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 15–17; Ni, 5–7; C, 0.12–0.2; Mn, 4.5 max; Si, 0.75 max.	Strip only
45	**Endure 16–6X**	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 16–18; Ni, 7–8.5; C, 0.1–0.2; Mn, 1.5 max; Si, 0.75 max.	Strip only
46	**Endure 18–8†****	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 17–19; Ni, 7–9; C, 0.08–0.20; Mn, 0.60 max; Si, 0.75 max.	HR, CR, D, P, S, T, W, B
47	**Endure 18–8B**	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 17–19; Ni, 7–9.5; Mn, 1.5; Si, 2–3; P & S, 0.03; C, 0.08–0.20	S, B, strip
48	**Endure 18–8SMo**	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 16–19; Ni, 9–14; Mo, 2–4; Si, 0.75; P & S, 0.03 max; C, 0.11 max.	P, S, B, strip
49	**Endure HCN**	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 22–26; Ni, 11–14; C, 0.20 max; Mn, 1.5 max; Si, 2.0, D; S	P, S, B, strip
50	**Fahrite N-2**	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 17–23; Ni, 7–10; C, 0.30 max.	C
51	**Fahrite N-3**	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 23–28; Ni, 10–13; C, 0.50 max; Mn, 0.5–1.0	C
52	**Heat Resisting 5**	Jessop Steel Co., Washington, Pa.	Fe; Cr, 22–26; Ni, 11–13; C, 0.20 max; Mn, 1.50 max.	HR, CR, P, S, B
53	**Heat Resisting 5B**	Jessop Steel Co., Washington, Pa.	Fe; Cr, 24–26; Ni, 19–21; C, 0.25 max; Mn, 0.75	HR, CR, P, S, B
54	**Hi-Gloss**	Jessop Steel Co., Washington, Pa.	Fe; Cr, 17–19; Ni, 7–9.5; C, 0.12 max; Mn, 0.50 max.	HR, CR, P, S, B
55	**Hi-Gloss FM**	Jessop Steel Co., Washington, Pa.	Fe; Cr, 17–19; Ni, 7–9.5; C, 0.12 max; Se, 0.22–0.26; Mn, S, P	HR, CR, P, S, B
56	**IngAclad 306****	Ingersoll Steel & Disc Div., Borg-Warner Corp., Chicago, Ill.	Fe; Cr, 18–20; Ni, 8–10; C, 0.11 max.‡	HR, P, S
57	**IngAclad 316**	Ingersoll Steel & Disc Div., Borg-Warner Corp., Chicago, Ill.	Fe; Cr, 16–19; Ni, 14 max; C, 0.10 max; Mo, 2–4‡	HR, P, S
58	**Lesco 18–8**	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 18.5; Ni, 8.5; C, 0.20 max; Mn, 0.40; Si, 0.50 max.	HR, CR, D, P, S, T, W, B
59	**Lesco 18–8 S**	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 18.5; Ni, 8.5; C, 0.07 max; Mn, 0.40; Si, 0.50 max.	HR, CR, D, P, S, T, W, B
60	**Lesco 21–12**	Latrobe Elec. Steel Co., Latrobe, Pa.	Fe; Cr, 21; Ni, 12; C, 0.20 max; Mn, 0.40; Si, 0.50 max.	HR, CR, D, P, S, W, B
61	**Midvaloy 18–8**	Midvale Co., Philadelphia, Pa.	Fe; Cr, 18; Ni, 9; C	HR, C, B, Fr
62	**Midvaloy 25–10**	Midvale Co., Philadelphia, Pa.	Fe; Cr, 24; Ni, 11; C	HR, C, B
63	**Milwaloy 26**	Milwaukee Steel Foundry Co., Milwaukee, Wis.	Fe; Cr, 18–20; Ni, 8–10; C, 0.08–0.12	
64	**Milwaloy 38**	Milwaukee Steel Foundry Co., Milwaukee, Wis.	Fe; Cr, 28–30; Ni, 8–10; C, 0.12–0.15	
65	**Misco 18–8**	Michigan Steel Casting Co., Detroit, Mich.	Fe; Cr, 19; Ni, 9; C, 0.15; Mn, 0.50	C, HR, P, S, B
66	**Misco B**	Michigan Steel Casting Co., Detroit, Mich.	Fe; Cr, 25; Ni, 13; C, 0.25; Mn, 0.60	C, HR, P, S, B
67	**Misco C**	Michigan Steel Casting Co., Detroit, Mich.	Fe; Cr, 29; Ni, 9; C, 0.25; Mn, 0.60	C, HR, B, P, S
68	**Nirosta**	Driver-Harris Co., Harrison, N. J.	Fe; Cr, 16.5–19.5; Ni, 7–10	HR, CR, D, P, S, T, W, B
69	**Nirosta 17–7**	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 16–18; Ni, 7–8.5; C, 0.1–0.2	HR, CR, D, W, B
70	**Nirosta 19–9**	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 18–20; Ni, 8–10; C, 0.08–0.2	HR, CR, D, W, B
71	**Nirosta FC**	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 18.5; Ni, 9; C, 0.16 max; Se, 0.25	CR, D, W, B
72	**Nirosta KA2**	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 17–19; Ni, 7–9.5; C, 0.08–0.2; Mn, 0.6	HR, CR, D, W, B
73	**Nirosta KA2S**	Firth-Sterling Steel Co., McKeesport, Pa.	Fe; Cr, 17–19; Ni, 7–9.5; C, 0.11 max.	HR, CR, D, W, B
74	**Nirosta Calmar KA2**	Warman Steel Casting Co., Huntington Park, Calif.	Fe; Cr, 18; Ni, 8	C
75	**Otisel 1**	Otis Elevator Co., Buffalo, N. Y.	Fe; Cr, 18–20; Ni, 8–10; C, 0.1–0.12; Mn, 0.6–0.7	C
76	**Otisel 4**	Otis Elevator Co., Buffalo, N. Y.	Fe; Cr, 20–30; Ni, 10–20; C, 0.1–0.12; Mn, 0.6–0.7	C
77	**Q-Alloy CN-1**	General Alloys Co., Boston, Mass.	Fe; Cr, 22–26; Ni, 10–12; C	C, HR, CR, P, S, W, B
78	**Q-Alloy CN1-H**	General Alloys Co., Boston, Mass.	Fe; Cr, 28–32; Ni, 10–13; C	
79	**Q-Alloy CN1-Mo**	General Alloys Co., Boston, Mass.	Fe; Cr, 22–26; Ni, 10–12; C; Mo, 0.5–2.0	C, HR, P, S, W, B
80	**Q-Alloy CN-2**	General Alloys Co., Boston, Mass.	Fe; Cr, 17–21; Ni, 7–9; C	C, HR, CR, P, S, W, B, T
81	**Rezistal 2C**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 17–19; Ni, 7–9; C, 0.08–0.20; Si, 2–3	
82	**Rezistal 3**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 21–26; Ni, 10–13; C, 0.20 max.	
83	**Rezistal KA2**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 17–19; Ni, 7–9; C, 0.08–0.20	
84	**Rezistal KA2SMo**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 16–20; Ni, 7–11; C, 0.07 max; Mo, 2–4	
85	**Rezistal KA2ST**	Crucible Steel Co., New York, N. Y.	Fe; Cr, 17–19; Ni, 7–9; C, 0.07 max; Ti, 0.35 min.	
86	**Rustless 18–8–3Mo**	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 16–19; Ni, 14.0 max; Mo, 2–4; C, 0.09 max.	HR, D, W, B
87	**Rustless 25–12**	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 22–26; Ni, 11–13; C, 0.20 max.	HR, D, W, B
88	**Silcreme 25–12**	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 22–26; Ni, 11–13; C, 0.20 max; Mn, 1.20	HR, D, W, B
89	**Silcreme KA2**	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 17–19; Ni, 7–9; C, 0.20 max; Mn, 0.60 max.	HR, CR, D, P, S, W, B
90	**Silcreme KA2-C**	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 17–19; Ni, 8–12; C, 0.15 max; Mn, 0.75 max; Cb, 6–10 x C	HR, D, P, S, W, B
91	**Silcreme KA 2-EZ**	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 17–19; Ni, 7–9.5; C, 0.20 max; Mn, 1.0; Se, 0.25; P, 0.12	HR, D, W, B
92	**Silcreme KA2-S**	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 17–19; Ni, 7–9.5; C, 0.11 max; Mn, 0.60 max.	HR, CR, D, P, S, W, B
93	**Silcreme KA2-SM**	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 17–19; Ni, 7–11; C, 0.11 max; Mn, 1.2 max; Mo, 2–4	HR, D, P, S, W, B
94	**Silcreme KA2-T**	Ludlum Steel Co., Watervliet, N. Y.	Fe; Cr, 17–19; Ni, 7–9; C, 0.20 max; Mn, 0.60 max; Ti, 4 x C	HR, D, P, S, W, B
95	**Sivyer 60**	Sivyer Steel Casting Co., Milwaukee, Wis.	Fe; Cr, 18; Ni, 8; C, 0.12 max; Mn, 0.50	C
96	**Sivyer 62**	Sivyer Steel Casting Co., Milwaukee, Wis.	Fe; Cr, 23–25; Ni, 11–13; C, 0.15 max; Mn, 0.50	C
97	**Stainless N**	Vanadium Alloy Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 18.5; Ni, 9; C, 0.12 max; Mn, 0.35	HR, D, P, S, W, B
98	**Stainless U**	Vanadium Alloy Steel Co., Colonial Steel Co., Pittsburgh, Pa.	Fe; Cr, 19; Ni, 9; C, 0.12 max; Cu, 1; Mo, 1	HR, CR, D, P, S, W, B
99	**Tisco 28–11**	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 26–30; Ni, 8–12; C, 0.30 max; Mn, 1.00 max.	C
100	**Tisco KA2†**	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 16.5–20; Ni, 7–10.5; C, 0.16 max; Mn, 1.00 max.	C
101	**Tisco KA2Mo†**	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 18–22; Ni, 7–10.5; C, 0.16 max; Mo, 2–4; Mn, 1.00 max.	C
102	**Tisco KA2S†**	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 16.5–20; Ni, 7–10.5; C, 0.07 max; Mn, 1.00 max.	C
103	**Tisco KA2SMo†**	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 18–22; Ni, 7–10.5; C, 0.07 max; Mo, 2–4; Mn; 1.00 max.	C
104	**Uniloy 18–8†**	Universal Steel Co., Bridgeville, Pa.; also	Fe; Cr, 17–19; Ni, 8–10; C, 0.05–0.2; Mn, 0.25–0.7	HR, CR, D, P, S, W, B
105	**Uniloy 24–11**	Cyclops Steel Co., Titusville, Pa.	Fe; Cr, 22–28; Ni, 12–16; C, 0.05–0.25; Mn, 0.5–0.7	HR, CR, D, P, S, W, B
106	**USS18–8****	Carnegie-Illinois Steel Co., Pittsburgh, Pa.	Fe; Cr, 17 min; Ni, 7 min; C, 0.12 max; Mn, 0.50 max; Si, 0.50 max.	HR, CR, D, P, S, T, W, B
107	**USS 25–12**	Carnegie-Illinois Steel Co., Pittsburgh, Pa.	Fe; Cr, 22–26; Ni, 11–15; C, 0.20 max; Mn, 2.0 max.	HR, CR, D, P, S, W, B
108	**48 Alloy**	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 28; Ni, 8; C, 0.50 max.	C, HR, CR, P, S, B
109	**49 Alloy**	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 17–23; Ni, 7–10; C	
110	**63 Alloy**	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 26–30; Ni, 10–12; C	
111	**100 Alloy**	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 25; Ni, 12; C, 0.50 max.	C, HR, B, S

* Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; Fr, forgings; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.
† Also available with Se addition to give free machining.
** Also available with Cb or Ti addition.
‡ Refers to stainless surface which comprises approximately 20 per cent of the total sheet or plate thickness.

Highly Alloyed Metals

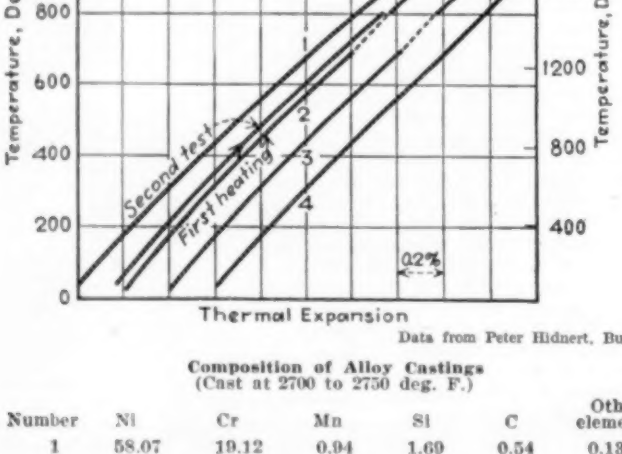
THERE is a large number of very high chromium, nickel-iron alloys that are useful for unusually severe conditions in the process industries. The chromium content is generally between 10 to 35 per cent and the nickel from 10 to 80 per cent. Resistance to oxidation increases with increase in chromium up to about 30 per cent. The combination of iron and nickel imparts good creep resistance.

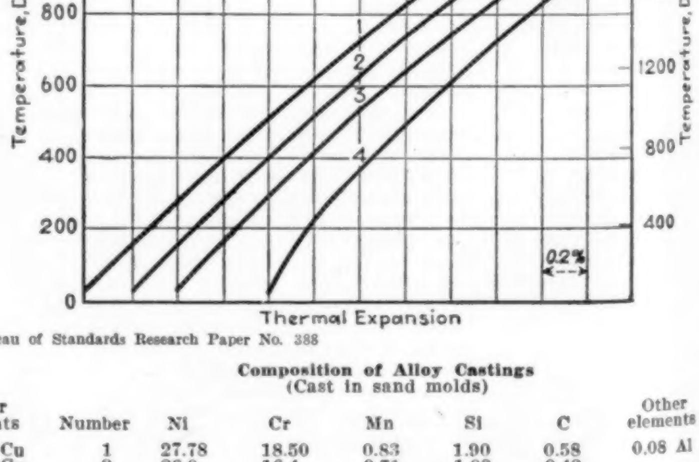
Those alloys of about 60 per cent nickel and 15 per cent chromium are particularly applicable where toughness, resistance to oxidation, nitriding and carburization and high electrical resistivity are demanded. While the alloys of 30 to 40 per cent nickel and 15 to 20 per cent chromium are principally used for furnace construction, alloys containing 10 to 20 per cent nickel and 25 to 30 per cent chromium find many uses in chemical roasting equipment and in furnaces in which a sulphidizing atmosphere will be present. Another type consists of 75 to 80 per cent nickel and 12 to 20 per cent chromium and only about 5 per cent iron. These materials have excellent resistance to oxidation at temperatures up to 2,000 deg. F., however, they are not recommended for service above 1,000 deg. F. in reducing sulphidizing atmospheres.

There have been two quite recent developments along this line which make it possible to operate resistance furnaces at considerably higher temperatures than heretofore. These new alloys do not contain nickel but are relatively high in chromium and aluminum. One of these is a Swedish development, although the alloy is available in this country. It contains about 60 per cent iron, the balance being mainly chromium, aluminum and cobalt. The other alloy contains approximately 37.5 per cent chromium and 7.5 per cent aluminum. Both alloys are said to be suitable for continuous service up to very nearly 2,400 deg. F.

The picture illustrates the use of a 25 per cent nickel, 17 per cent chromium, $2\frac{1}{2}$ per cent silicon iron alloy for carburizing pots heated at temperatures up to 1,800 deg. F.

Linear thermal expansion of two types of high nickel-chromium cast alloys satisfactory for resisting high temperatures





Data from Peter Hidnert, Bureau of Standards Research Paper No. 388

Composition of Alloy Castings
(Cast at 2700 to 2750 deg. F.)

Number	Ni	Cr	Mn	Si	C	Other elements
1	58.07	19.12	0.94	1.69	0.54	0.18 Cu
2	61.00	15.70	0.62	0.69	0.95	0.78 Cu
3	65.22	16.23	1.40	1.18	0.59	
4	70.1	16.3	3.23	2.51	0.94	

Composition of Alloy Castings
(Cast in sand molds)

Number	Ni	Cr	Mn	Si	C	Other elements
1	27.78	18.50	0.83	1.90	0.58	0.08 Al
2	36.0	16.4	0.71	1.03	0.42	
3	40.3	21.1	1.43	1.91	0.44	0.1 Cu
4	41.98	12.12	0.55	0.81	0.43	

PHYSICAL PROPERTIES OF HIGHLY ALLOYED METALS

No.	MATERIAL	Specific Gravity	Melting Point °F.	Mean Coeff. Therm. Exp. 32-212° F. x 10^6	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation % in 2in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10^{-6}	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
1	Amsco F-1	7.9-8.2	2550-2650	0.70	0.03	Cast	50-70	40-50	15-35	15-40		150	Fair	Yes	W
2	Amsco F-3	7.5	2550-2630	1.00	0.059	Cast	40-60	30-45	0-2	0-5		170	Fair	Yes	W
3	Amsco F-5	8.0	2550	0.90	0.035	Cast	50-70	35-45	20-40	20-40		180-200	Fair	Yes	W
4	Amsco F-6													Yes	W
5	B & W 700	8.2		0.76	0.032	Annealed bar	95	50	35	40	29		Fair	No	F, R, W, B
6	B & W 1100	7.9		0.95	0.035	Annealed bar	90	40	45	55		160	Fair	No	DD, F, R, W, B
7	B & W 1300	8.15		0.75	0.027	Cast	60	35					Fair	No	W, B
8	Calite A	7.86	2750	0.96		Cast	65-70	30-35	15	15		200	Fair	Fair	
9	Calite N	8.22	2750	0.85		Cast	70-75	40-45	8-10	8-10		190	Fair	No	
10	Chromax	7.99	2516	0.71	0.031	Cast	62		2.0				Good	No	
11	Chromax	7.99	2695	0.70	0.031	Wrought	102		30				Good	No	DD, F, R, W, B
12	Chromel 502	7.84	2450	0.95		Cast	65-75		3			160-180	Good		R, W, B
13	Circle L18	6.90	2850-2900	1.00				Very fragile at room temp.				200-235	Limited		
14	Circle L 24	8.0	2600-2700	1.00	0.074	Forged and rolled	60	25	50	40	28	125	Fair	Slight	
15	Circle L 32	8.0	2575-2675	0.78			75	30	7	7		185	Good	Slight	
16	Circle L 34						72	35	45	45		150	Good	No	
17	Cooper Alloy 18	7.9	2700	1.02	0.069	Cast	79	46.5	23	24		150	Good	No	
18	Cooper Alloy 21	7.9	2700	1.02	0.069	Cast	62	48	12	10		170	Good	No	
19	Cooper Alloy 21A,B & C	7.9	2700	1.02		Cast	75	40	25	24		160	Good	No	
20	Cooper Alloy 23	8.0	2700	1.11	0.04	Cast	70	35	24	50		140	Good	No	
21	Croloy 25-20	7.9	2540-2600	0.89	0.051	Annealed tube	80-105	35-65	45-60		30	130-180	Fair	Fair	F, W
22	Cyclops 17A	8.0		0.93	0.065	Annealed	100-125	40-65	25	50	28	167-228	Good	Fair	DD, F, R, W
23	Cyclops 17B	8.0		0.93	0.065	Annealed	80-90	25-40	40	60	28	128-160	Good	No	DD, F, R, W, B
24	Defiheat	7.6		0.61	0.05	Bar	77	55	28	50	29	163	Fair	No	R, W, B
25	Duraloy 35-15					Cast	70	45	2	2			Fair	No	
26	Durco D-10	8.2	2500	0.78		Cast	65					175	Fair	No	
27	Durimet	7.77	2650	0.78	0.05	Cast	68-72	30-33	40-45	47-52		130	Good	No	W
28	Economet					Cast	65-70	53-56					Machinable		R, W
29	Elcomet K												Fair	Yes	R, W, B
30	Empire 4														
31	Enduro NC-3	7.8	2600	0.85	0.03	Annealed	95	45	45		29	187	Fair	Yes	DD, F, R, W
32	Evansteel 2						115-125		15-20	25-30		275			
33	Fahrite N-1	8.15				Cast	60	27					Machinable		W
34	Fahrite N-5					Cast							Machinable		W
35	Fahrite N-6														W
36	Fire Armor	8.14		0.78		Cast	60	46	2	2.9		190	Fair		
37	HR-5M	7.8	2800	0.85		Cast	62	51	18	13		190-210	Fair	Good	R, W, B
38	Kanthal A						106-114			64		230			
39	Kanthal A-1						106-114		13	65		230			
40	Kanthal D						106-114			65		200			
41	Lesco 25-20					Annealed bar	117	57	40	54		217	Fair		DD, F, R, W, B
42	Midvaloy 1835	7.93		0.74		Cast	55-65	40-45	5-12	10-20		150-170	Fair	Good	F, R, W, B
43	Midvaloy 25-20	7.8				Wrought	85-100	40-50	25-40	24-50		170-200	Fair	Good	F, R, W, B
44	Midvaloy 30-30	7.84				Cast annealed		42.5					Poor	Good	W
45	Midvaloy A.T.V.-1	8.05	2640		0.02	Wrought	88-110	50-68	20-35	30-54		170-185	Good	Good	R, W
46	Midvaloy A.T.V.-3	8.12		0.78		Wrought	100-112	45-70	24-33	40-45		185-238	Good		R, W
47	Milwaloy 50														
48	Misco HN-2					Cast	75	45	3	5	22.4	200	Good		R, W
49	Misco Metal			0.76		Cast	60	40	3	4	23	200	Good	Yes	W
50	Nichrome	8.25	2462	0.76	0.03	Wrought	100	60	35	50			Good	No	DD, F, R, W, B
51	Nichrome (Cast)	8.15	2460	0.62	0.033	Cast	65		2.0	3.5			Good	No	
52	Nirosta Calozo KNC3	7.3				Cast	75	35	25		27-28	200	Fair	Yes	
53	Premier Nickel Chrome		2500	0.76		Wire, rod, strip	100	60	25	50					
54	Pyrasteel	7.87	2640	0.95				42	10	18					DD, F, R, W
55	Q-Alloy A Plus					Cast	80	50				200	Machinable		R, W
56	Q-Alloy B					Cast	75	45				200			R, W
57	Q-Alloy C 3					Cast						500 min.		Very	
58	R-55						67	55	2	3		190	Fair	Yes	R, W, B
59	Rezistal 4	7.84		0.90		Annealed	90-110	45-50	30-40	35-45	28-30	160-190	Fair		W, R
60	Rezistal 7	7.72		0.89		Annealed	100-110	45-55	45-55	50-60	28-30	150-180	Fair		W, R
61	Rezistal 2600	7.98		0.93	0.074	Annealed	85-95	45-55	30-40	45-55	28-30	160-190	Machinable		W, R
62	Silcrome 25-20	8.0	2600	0.80	0.04	Annealed	90-110	35-60	40-55	45-60	30	140-200	Tough	Good	DD, F, R, W, B
63	Sivyer 70					Cast	60-70		1-7	1-8		200-225	Fair		
64	Smith No. 10											200-235			
65	Thermalloy B	7.90	2300-2500	0.61				10	4	10		241	Good		W
66	Tisco 15-35												Fair	No	
67	Tisco KNC 3						80-90	35-40	15-25	15-25		160-180	Fair	No	
68	Tophet A	8.42	2600-2740	0.73	0.036	Annealed wire	100	70	30	45		190	Good		W
69	Tophet C	8.2	2580-2720	0.76		Annealed	95	65	30	45		165	Good		W
70	Tophet D	7.94	2560-2700			Annealed	75		30				Good		R, W
71	Worthite	7.85	2600-2700	0.78		Cast	67-75	30-35	35-45	35-45		125-150	Good	Fair	R, W
72	X-ite					Cast	65-70	53-56					Machinable		R, W
73	X-ite B														
74	Zorite	8.05		0.83		Cast	65	45	5	4		180	Fair		

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

MAKERS OF THE HIGHLY ALLOYED METALS

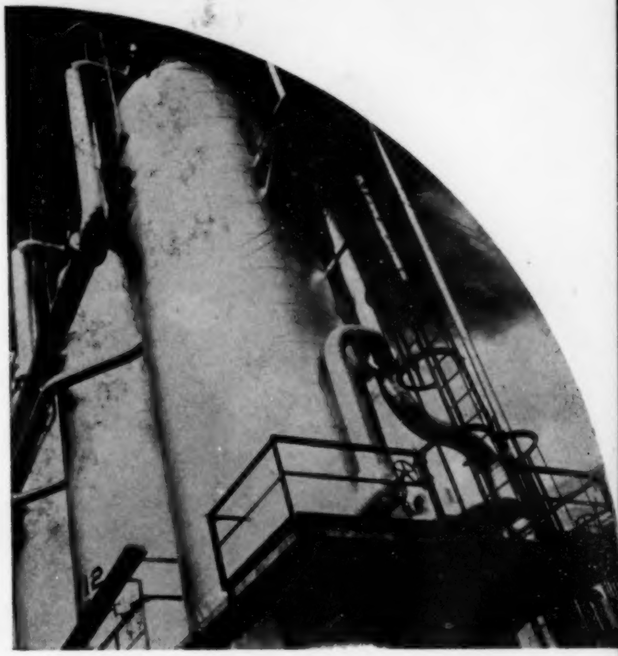
No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
1	Amsco F-1	Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe; Cr, 15–17; Ni, 34–36; C, 0.50; Mn, 1; Si, 1.5 max.	C
2	Amsco F-3	Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe; Cr, 27–29; Ni, 30 max; C, 0.30 max; Mn, 1.0 max; Si, 1.5 max.	C
3	Amsco F-5	Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe; Cr, 17–19; Ni, 65–68; C, 0.50 max; Mn, 1.0 max; Si, 1.5 max.	C
4	Amsco F-6	Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe; Cr, 12–14; Ni, 59–62; C, 0.50 max; Mn, 1.0 max; Si, 1.5 max.	C
5	B & W 700	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 16–20; Ni, 62–68; C, 0.60 max & 1.25 max; Si, 2.0–2.5	C
6	B & W 1100	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 24–26; Ni, 19–23; C, 0.15 max & 0.50 max; Si, 1.0–2.5	C
7	B & W 1300	Babcock & Wilcox Co., New York, N. Y.	Fe; Cr, 15–17; Ni, 35–38; C, 0.50 max; Si, 1.0–1.5	C
8	Calite A	Calorizing Co., Pittsburgh, Pa.	Fe; Cr, 15; Ni, 35	C, HR, CR, P, S, W, B
9	Calite N	Calorizing Co., Pittsburgh, Pa.	Fe; Cr, 17; Ni, 65	C
10	Chromax	Driver-Harris Co., Harrison, N. J.	Fe; Cr, 14–18; Ni, 34–38	C
11	Chromax	Driver-Harris Co., Harrison, N. J.	Fe; Cr, 15; Ni, 35	HR, CR, D, P, S, W, B, T
12	Chromel 502	Hoskins Mfg. Co., Detroit, Mich.	Fe, 38–48; Ni, 30–34; Cr, 18–22; Mn, 2; C, 0.50 max.	C, CR, HR, D, B, W
13	Circle L 18	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 37.5; C, 0.07 max; Al, 7.5	
14	Circle L 24	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 9; Ni, 20; C, 0.15	
15	Circle L 32	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 16; Ni, 35; C, 0.50	
16	Circle L 34	Lebanon Steel Fdry., Lebanon, Pa.	Fe; Cr, 20; Ni, 30; C, 0.07; Cu, 5	
17	Cooper Alloy 18	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 10; Ni, 22; C, 0.2; Mn, 0.5	C
18	Cooper Alloy 21	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 15; Ni, 65; C, 0.5; Mn, 0.5	C
19	Cooper Alloy 21 A,B,& C	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 15–20; Ni, 20–25; C, 0.7–0.12; Cu, 0.5–3; Mn, 0.5	C
20	Cooper Alloy 23	Cooper Alloy Fdry. Co., Elizabeth, N. J.	Fe; Cr, 2; Ni, 40; C, 0.20; Mn, 0.50	C
21	Croloy 25–20	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; Cr, 25; Ni, 20; C, 0.15 max; Mn, 1.00 max; Si, 0.75 max.	C, HR, CR, T
22	Cyclops 17A	Universal Steel Co., Bridgeville, Pa. and	Fe; Cr, 8–9; Ni, 20–21; C, 0.37–0.45; Mn, 0.5–0.7	HR, CR, D, P, S, T, W, B
23	Cyclops 17B	Cyclops Steel Co., Titusville, Pa.	Fe; Cr, 8–9; Ni, 20–21; C, 0.1–0.2; Mn, 0.5–0.7	HR, CR, D, P, S, T, W, B
24	Defiheat	Rustless Iron & Steel Corp., Baltimore, Md.	Fe; Cr, 23–30; C, 0.35 max.	HR, D, W, B
25	Duraloy 35–15	Duraloy Co., Pittsburgh, Pa.	Fe; Cr, 15; Ni, 35	C
26	Durco D-10	Duriron Co., Dayton, Ohio	Fe; Cr, 23; Ni, 57; Cu, 8; Mn, 1; Mo, 4; W, 2	C
27	Durimet	Duriron Co., Dayton, Ohio	Fe; Cr, 18; Ni, 22; C, 0.07 max; Si; Mo; Cu	C, HR
28	Economet	General Alloys Co., Boston, Mass.	Fe; Cr, 8–12; Ni, 29–32	C
29	Elcomet K	La Bour Co., Elkhart, Ind.	Fe, 46; Cr, 24; Ni, 22; C, 0.13; Cu, 3.5; Mo, 2; Si, 1.25; Mn, 0.30	C
30	Empire 4	Empire Steel Castings, Inc., Reading, Pa.	Fe; Cr, 13–17; Ni, 34–37	
31	Enduro NC-3	Republic Steel Corp., Massillon, Ohio	Fe; Cr, 24–26; Ni, 19–21; C, 0.25 max; Mn, 1.5 max; Si, 2 max.	P, S, B
32	Evansteel 2	Chicago Steel Fdry. Co., Chicago, Ill.	Fe; Cr; Ni	
33	Fahrite N-1	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 13–17; Ni, 34–37; C, 0.60 max; Mn, 0.4–0.9	C
34	Fahrite N-5	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 10–14; Ni, 59–62; C, 0.80 max; Mn, 0.4–0.9	C
35	Fahrite N-6	Ohio Steel Fdry. Co., Springfield, Ohio	Fe; Cr, 15–19; Ni, 65–68; C, 0.80 max; Mn, 0.4–0.9	C
36	Fire Armor	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 15–19; Ni, 65–68	C, HR, CR, P, S, B
37	HR-5M	Standard Alloy Co., Cleveland, Ohio	Fe; Cr, 25; Ni, 20; C, 0.30; Mo, 2.5–4; Mn, 0.40	C
38	Kanthal A	C. O. Jelliff Mfg. Corp., Southport, Conn.	Fe, bal; Cr; Al; Co	W
39	Kanthal A-1	C. O. Jelliff Mfg. Corp., Southport, Conn.	Fe, bal; Cr; Al; Co	W
40	Kanthal D	C. O. Jelliff Mfg. Corp., Southport, Conn.	Fe, bal; Cr; Al; Co	W
41	Lesco 25–20	Latrobe Electric Steel Co., Latrobe, Pa.	Fe; Cr, 15; Ni, 20; C, 0.20 max; Mn, 0.40; Si, 0.95 max.	CR, HR, D, B
42	Midvaloy 1835	Midvale Co., Philadelphia, Pa.	Fe; Cr, 18; Ni, 35; C, 0.35	C, HR, B
43	Midvaloy 25–20	Midvale Co., Philadelphia, Pa.	Fe; Cr, 25; Ni, 19.5; C, 0.12	C, HR, T, B
44	Midvaloy 30–30	Midvale Co., Philadelphia, Pa.	Fe; Cr, 27; Ni, 30; C, 0.50	C
45	Midvaloy A.T.V. 1	Midvale Co., Philadelphia, Pa.	Fe; Cr, 11–15; Ni, 36; C, 0.35	C, HR, B
46	Midvaloy A.T.V. 3	Midvale Co., Philadelphia, Pa.	Fe; Cr, 14; Ni, 26.5; C, 0.48; W, 3.5	C, HR, B
47	Milwaloy 50	Milwaukee Steel Foundry Co., Milwaukee, Wis.	Fe; Cr, 15–18; Ni, 32–36; C, 0.30–0.40	
48	Misco HN-2	Michigan Steel Casting Co., Detroit, Mich.	Fe; C, 0.70 max; Cr, 14; Ni, 60; Mn, 0.60	
49	Misco Metal	Michigan Steel Casting Co., Detroit, Mich.	Fe: C, 0.50; Cr, 15; Ni, 35; Mn, 0.60	C, HR, P, S, B
50	Nichrome	Driver-Harris Co., Harrison, N. J.	Fe, 25; Cr, 15; Ni, 60	C, CR, HR, D, P, S, T, W, B
51	Nichrome (Cast)	Driver-Harris Co., Harrison, N. J.	Fe; Cr, 11–13; Ni, 59–61	C
52	Nirosta Caloxo KNC 3	Warman Steel Casting Co., Huntington Park, Calif.	Fe; Cr, 25; Ni, 20	C
53	Premier Nickel Chrome	Alloy Metal Wire Co., Moore, Pa.	Fe, 25; Cr, 14–16; Ni, 60–62; C, 0.10	CR, W, B
54	Pyrasteel	Chicago Steel Fdry. Co., Chicago, Ill.	Fe, 57; Cr, 15; Ni, 25; C, 0.30	C, HR, S, T, W, B
55	Q-Alloy A Plus	General Alloys Co., Boston, Mass.	Fe; Cr, 15–19; Ni, 65–68	C, HR, P, S, W, B
56	Q-Alloy B	General Alloys Co., Boston, Mass.	Fe; Cr, 10–14; Ni, 59–62	C, HR, P, S, W, B
57	Q-Alloy C-3	General Alloys Co., Boston, Mass.	Fe; Cr, over 30; C, over 1.0	C
58	R-55	La Bour Co., Elkhart, Ind.	Fe, 8; Cr, 23; Ni, 52; Cu, 6; Mo, 3.6; W, 1.8; Si, 4; C, 0.20	C
59	Rezistal 4	Halcomb Steel Co., Syracuse, N. Y. Crucible Steel Co., New York, N. Y.	Fe; Cr, 19–21; Ni, 24–26; C, 0.25 max.	
60	Rezistal 7	Halcomb Steel Co., Syracuse, N. Y. Crucible Steel Co., New York, N. Y.	Fe; Cr, 24–26; Ni, 19–21; C, 0.25 max.	
61	Rezistal 2600	Halcomb Steel Co., Syracuse, N. Y. Crucible Steel Co., New York, N. Y.	Fe; Cr, 7–10; Ni, 21–23; C, 0.25 max; Cu, 1.00–1.50	
62	Silcrome 25–20	Ludlum Steel Co., Watervliet, N. Y.	Fe: Cr, 24–26; Ni, 19–21; C, 0.25 max; Mn, 1.2 max.	HR, D, W, B
63	Sivyer 70	Sivyer Steel Casting Co., Milwaukee, Wis.	Fe; Cr, 15–17; Ni, 35–37; C, 0.60 max.	C
64	Smith No. 10	Hevi-Duty Elec. Co., Milwaukee, Wis.	Fe; Cr, 37.5; Al, 7.5	
65	Thermalloy B	Electro Alloys Co., Elyria, Ohio	Fe; Cr, 20; Ni, 40; C, 0.4–0.6; Mn, 1.5; Si, 1.5	C
66	Tisco 15-35	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 15–18; Ni, 35–40; C, 0.50 max; Mn, 1.00 max.	C
67	Tisco KNC 3	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 23–27; Ni, 17–21; C, 0.20 max; Mn, 1.00 max.	C
68	Tophet A	Wilbur B. Driver Co., Newark, N. J.	Cr, 20; Ni, 80	HR, CR, D, W, B
69	Tophet C	Wilbur B. Driver Co., Newark, N. J.	Fe; Cr, 15; Ni, 60	HR, CR, D, W, B
70	Tophet D	Wilbur B. Driver Co., Newark, N. J.	Fe; Cr, 20; Ni, 70	HR, CR, D, W, B
71	Worthite	Worthington Pump & Mach. Co., Harrison, N. J. Lebanon Steel Fdry. (licensee), Lebanon, Pa.	Fe; Cr, 20; Ni, 24; C, 0.07 max; Mo, 3	C
72	X-ite	General Alloys Co., Boston, Mass.	Fe; Cr, 17–21; Ni, 37–40	C, HR, P, S, W, B
73	X-ite B	General Alloys Co., Boston, Mass.	Fe; Cr, 13–17; Ni, 34–37	C, HR, P, S, W, B
74	Zerite	Michiana Products Corp., Michigan City, Ind.	Fe; Cr, 15; Ni, 35	C, S, B, HR, CR, P

** Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.

THE low alloy steels contain as much as 3 per cent of the added metal, copper, nickel, chromium, silicon, molybdenum and vanadium. Their high tensile properties make them primarily substitutes for ordinary structural carbon steel. However, they are being used to a considerable extent in the process industries for equipment construction. While the corrosion resistance is not comparable to the highly alloyed steels, many of them have a resistance from 4 to 6 times as great as the plain steels.

These alloy steels can be welded easily. And they have excellent impact strength at low temperatures. The illustration shows the use of a 2½ per cent nickel steel for shells of vessels, low temperature pipe lines and cast steel valves and fittings. These pressure vessels operating at temperatures of —40 deg. F. are at the deasphalting and dewaxing plant of the Shell Petroleum Corp.'s refinery at Wood River, Ill.

Low-Alloyed Steels



Physical Properties of the Low-Alloyed Steels

No.	MATERIAL	Specific Gravity	Melting Point, °F.	Mean Coeff. Therm. Exp., 32-212° F. x 10⁶	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation, % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10⁻⁶	Brinell Hardness	Machining Qualities	Abrasion Resistant	Methods of Fabrication*
1	Armco HT-50					Hot and cold rolled sheets	66-70	47-52	25-28		29		Excel.		F, R, W
2	Carbon-Moly Steel					Annealed	47	26	30	60		150	Satisfactory	No	F, R, W
3	Circle L3	7.84		0.62	0.125		110-250	85-200	5-18	5-40		220-550	Good	Yes	
4	Circle L4	7.84		0.62	0.125		125-275	90-225	3-12	3-20		250-600	Fair	Yes	
5	Circle L8	7.84	2625-2725	0.64	0.125		90-200	60-150	6-20	10-50		170-1000	Good	Yes	
6	Copper-bearing Steel	7.86	2710-2750	1.04	0.115	Plate	60-72	30-36	22	40	29	131	Fair	No	R, W
7	Cor-Ten			0.67		Hot rolled	70	50	21.4		29-30	140-180	Good	Fair	DD, F, R, W
8	Croloy 2			0.74		Annealed	60	25	30		30	163	Fair		F, W
9	DM Steel					Annealed	60	25	30	60		170	Satisfactory	No	F, R, W
10	Empire 17						110	70	15	25		230			
11	Milwaloy 7														
12	Milwaloy 18														
13	Nickel-Moly Steel					Annealed	60	25	30	60		170	Satisfactory	No	F, R, W
14	Sicromo Steel					Annealed	60	25	30	60		170	Satisfactory	No	F, R, W
15	Tisco 41						115-130	60-80	6-12	8-20		220-235	Machinable	Yes	
16	Tisco 72						95-115	55-75	12-22	15-40		207-227	Machinable	Yes	
17	Yoloy	7.87	0.65	1.0-0.76		Hot rolled	65-95	45-66	24		30	130-200	Good	Yes	DD, F, R, W, B

* Methods of fabrication: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

Makers of the Low-Alloyed Steels

No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available**
1	Armco HT-50	Amer. Rolling Mill Co., Middletown, Ohio	Fe; C, 0.12 max; Ni, 0.25-0.75; Cu, 0.35-0.75; Mn, 0.20-0.80; Mo; P	HR, CR, P, S
2	Carbon-Moly Steel	Timken Steel and Tube Co., Canton, Ohio	Fe; C, 0.10-0.20; Mo, 0.45-0.65; Mn, 0.3-0.6; Si, 0.25 max; P; S	HR, D, T, B
3	Circle L3	Lebanon Steel Fdry., Lebanon, Pa.	Fe; C, 0.45; Cr, 1.25; Mo, 0.40; Mn, 1.40	
4	Circle L4	Lebanon Steel Fdry., Lebanon, Pa.	Fe; C, 0.50-0.80; Cr, 1.25-2.00; Mo, 0.50-1.00; Mn, 1.00-1.50	
5	Circle L8	Lebanon Steel Fdry., Lebanon, Pa.	Fe; C, 0.20; Cr, 2.75; Mo, 0.45; Va, 0.22	
6	Copper-bearing Steel	Jones & Laughlin Steel Corp. Pittsburgh, Pa.	Fe; C, 0.15-0.30; Cu, 0.20 min; Mn, 0.4-0.8	HR, P, S, B
7	Cor-Ten	Carnegie Illinois Steel Corp. Pittsburgh, Pa.	Fe; C, 0.10 max; Cr, 0.50-1.50; Cu, 0.30-0.50; Mn, 0.10-0.30; P	HR, CR, D, P, S, T, W, B
8	Croloy 2	Babcock & Wilcox Tube Co., Beaver Falls, Pa.	Fe; C, 0.15 max; Cr, 1.25-1.75; Mn, 0.30-0.60; Mo, 0.40-0.60	HR, CR, D, T, S, W, B
9	DM Steel	Timken Steel and Tube Co., Canton, Ohio	Fe; Cr, 1.0-1.5; C, 0.15 max; Mn, 0.3-0.6; Si, 0.5-1.0; Mo, 0.4-0.6	HR, D, T, B
10	Empire 17	Empire Steel Castings, Inc., Reading, Pa.	Fe; C, 0.30-0.35; Cr, 1.5; Mn, 0.6-0.8; Va, 0.5; Si, 0.4-0.5	C
11	Milwaloy 7	Milwaukee Steel Foundry Co., Milwaukee, Wis.	Fe; C, 0.30-0.40; Cr, 1.5-1.75; Va, 0.60-0.70	
12	Milwaloy 18	Milwaukee Steel Foundry Co., Milwaukee, Wis.	Fe; C, 0.30-0.45; Ni, 13-15; Mn, 3.9-4.5	
13	Nickel-Moly Steel	Timken Steel and Tube Co., Canton, Ohio	Fe; Ni, 1.5-2; Mo, 0.2-0.3; C, 0.1-0.2; Mn, 0.3-0.6; P; S; Si	HR, D, T, W, B
14	Sicromo Steel	Timken Steel and Tube Co., Canton, Ohio	Fe; Cr, 2.25-2.75; Si, 0.5-1.0; C,0.15 max; Mn, 0.5 max; Mo, 0.4-0.6	HR, D, T, B
15	Tisco 41	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Cr, 1.00-1.25; C, 0.45-0.55; Mn, 0.6-0.8	C
16	Tisco 72	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; C, 0.45-0.55; Cr, 0.80-1.00; Ni, 2.75-3.25; Mn, 0.6-0.8	C
17	Yoloy	Youngstown Sheet & Tube Co., Youngstown, Ohio	Fe; C, 0.06-0.25; Ni, 2.0 max; Mn 0.6; Cu, 1.00 max.	HR, CR, D, P, S, T, W, B

** Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; HR, hot rolled; P, plates; R, rods; S, sheets; T, tubing; W, wire.

Abrasion Resistant Alloys

In order to prevent excessive wear due to grinding, crushing, etc., which develops red heat and thus softens metal, several types of abrasive resistant materials are available. Among the most important are: a metal that is hard throughout, an ordinary metal whose surface is hardened, and an ordinary metal which is covered with about ⅛ in. of hard surfacing material. Such resistant metals will increase the life of the piece of equipment several times. This results in direct economy, as the hard metal or special surfacing treatments costs much less than the purchase price of the replacement parts that would otherwise be necessary. In addition, indirect savings are effected because it is not necessary to shut down the machine as frequently for repairs. Usually these materials are also corrosion resistant.

The illustration shows Stellited bearings of a cement screw conveyor.

Physical Properties of Abrasion Resistant Alloys

No.	MATERIAL	Specific Gravity	Melting Point °F.	Mean Coeff. Therm. Exp. 32-212° F. x 10⁶	Therm. Conduc. C. G. S. Unit, Room Temp.	Form for which Tensile Prop. are Recorded	Tensile Strength, 1,000 Lb. per in.²	Yield Point 1,000 Lb. per in.²	Elongation % in 2 in.	Reduc. of Area, %	Elastic Modulus, Lb. per in.² x 10⁻⁶	Brinell Hardness	Machining Qualities	Abrasive Resistant	Methods of Fabrication*
1	Amsco Mn Steel		2500-2600	1.00	0.023	Waterq'nch from 1850°F	100-130	35-50	40-60	30-50		185-200	Difficult	Very	W
2	AR Steel					Plate, bar	100-125				29-30	200-250	Fair	Excel.	F, R, W
3	Carbon-Mn AR Steel	7.85	2680-2720	1.15	0.115	Plate	95	52	15	35			Fair	Yes	R, W
4	Colmonoy 3	8.26	2135-2142			Cast bar	47		0	0		645-690	Unmchble.	Excel.	W
5	Colmonoy 6	7.80	1800-1900	0.89		Cast bar	26		0	0		543-587	Unmchble.	Excel.	W
6	Colmonoy 7	7.56	2152-2375			Cast	10.3								
						Hardened	21.4					300-665	Machinable	Good	W
7	Duraloy A	7.60	2650	0.67		As cast	50	40	1	1			Good	Good	R, W
8	Empire 14						45	65	25	35		240		Yes	
9	Hascrome	7.76	2462	0.72-1.1		Cast	90		0.5	0.5		250-500	Unmchble.	Good	W, B
10	Meehanite Metal	7.49	2480-2515	0.58	0.035	Heat treated	70	45			21	600 max	Free	Good	W
11	Nitralloy EZ	7.74	2700	0.73		Heat treated bar	100-125	70-90	15-20	30-45	30	220-250	Good	Very	Mach. only
12	Stellite No. 1	8.59	2280	0.66		As cast	54		0.5 max	0	35	555	Unmchble.	Excel.	W, B
13	Stellite No. 6	8.38	2330	0.78	0.035	As cast	100		1.0	1.0	30.4	364	Unmchble.	Excel.	W, B
14	Stellite No. 12	8.40	2305	0.70		Weld metal	99		0	0		394	Unmchble.	Excel.	W, B, Casting
15	Tisco Manganese					Bar	80-110	35-45	15-35	15-35		180-200	Unmchble.	Good	
16	Tisco Timang Rod 4					Rod	135-155	45-55	50-80	35-50		170-210	Unmchble.	Yes	W

* Methods of fabribation: B, brazing; DD, deep drawing; F, flanging; R, riveting; W, welding.

Makers of Abrasion Resistant Alloys

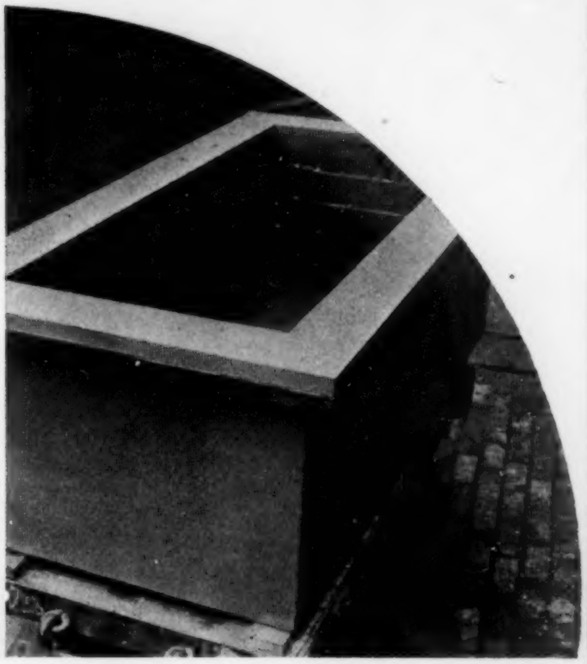
No.	MATERIAL	MANUFACTURER (Name and Address)	Essential Nominal Chemical Composition, Per Cent	Forms Available*
1	Amsco Mn Steel	Amer. Manganese Steel Co., Chicago Heights, Ill.	Fe; Mn, 10-14; C, 1-1.4; Si, 1.50 max.	C
2	AR Steel	Carnegie-Illinois Steel Corp., Pittsburgh, Pa.	Fe; C, 0.35-0.50; Mn, 1.5-2.0; Cu, 0.20 min, optional	HR, P, S, B
3	Carbon-Mn AR Steel	Jones & Laughlin Steel Corp., Pittsburgh, Pa.	Fe; C, 0.40-0.50; Mn, 1.0-1.7; Si, 0.10-0.30	HR, P, S, T, W, B
4	Colmonoy 3	Colmonoy Co., Los Nietos, Calif.	Fe, 58-84; Cr, 12.5-13; C + Si, 1.0; W, 15-22; B, 3-5	C, W, B
5	Colmonoy 6	Colmonoy Co., Los Nietos, Calif.	Ni, 68-82; Cr, 11-13; C + Si, 1.5; B, 2.5-5	C, W, B
6	Colmonoy 7	Colmonoy Co., Los Nietos, Calif.	90% low C steel fused with 10% CrB crystals	C
7	Duraloy A	Duraloy Co., Pittsburgh, Pa.	Fe, 69-72; Cr, 27-30; C, 0.25; Mn, 0.50	C,HR, CR, D, P, S, T, W, B
8	Empire 14	Empire Steel Castings, Inc., Reading, Pa.	Fe; C, 0.30-0.35; Cr, 1.0-1.5; Mn, 0.6-0.8; Si, 0.4-0.5; Mo, 0.25-0.30	C
9	Hascrome	Haynes Stellite Co., Kokomo, Ind.	10-14 Cr steel	C, weld rod
10	Meehanite Metal	Meehanite Metal Corp., Pittsburgh, Pa.	Fe; C, 3.0; Si, 0.5-6.0; Mn, 0.4-2.0; S, 0.05-0.12; P, 0.05-0.10	C
11	Nitralloy EZ	Ludlum Steel Co., Watervliet, N. Y.	Fe; C, 0.30-0.40; Cr, 1.00-1.50; Mn, 1.10 max; Mo, 0.15-0.25; Se, 0.15-0.25; Al, 0.75-1.5	HR, D, B
12	Stellite No. 1	Haynes Stellite Co., Kokomo, Ind.	Co; Cr; W	Weld rod
13	Stellite No. 6	Haynes Stellite Co., Kokomo, Ind.	Co; Cr; W	C, HR, P, S, weld rod
14	Stellite No. 12	Haynes Stellite Co., Kokomo, Ind.	Co; Cr; W	C, weld rod
15	Tisco Manganese	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; C, 1.00-1.40; Mn, 11-14	C
16	Tisco Timang Rod 4	Taylor-Wharton Iron & Steel Co., High Bridge, N. J.	Fe; Mn, 13-15; C, 0.6-0.8; Ni, 2.75-3.25	C, HR, D, S, W, B

* Forms available: B, bars; C, castings; CR, cold rolled; D, drawn; Fr, forgings; HR, hot rolled; P, plates; R, rods; S, sheets; T tubing; W, wire.

OWING to its not being attacked by many of the most corrosive materials met in chemical industries, structural carbon is coming into increasing prominence. It successfully resists such materials as strong alkalis, hydrofluoric and phosphoric acids at high temperatures, and is unaffected by most oxidizing agents, with the exception of air and oxidizing gases at red heat, and such strong oxidizing solutions as chromic and fuming sulphuric acid. It is available in a wide variety of forms and can be readily worked and machined with ordinary tools. Its abrasion resistance is said to be good.

Among the uses to which it has been put may be mentioned pulp digesters, Cottrell precipitator tubes, pickling tanks and equipment for handling corrosive gases. The drawings below suggest how tanks may be lined with carbon bricks.

Carbon

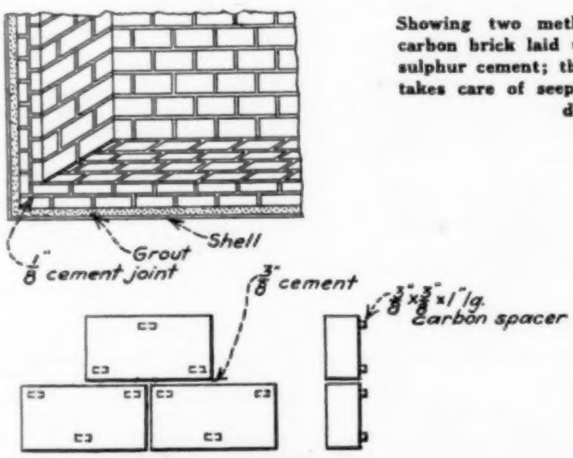


Physical Properties of Structural Carbon

(Available in rods, tubes, brick, tile, packing rings, plates and special shapes)

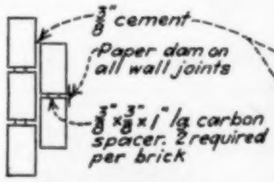
Specific gravity	2.00-2.10	Coef. of therm. expansion, per °C	0.000,000,72
Apparent density	1.53-1.64	Specific heat, cal. per gm., °C. (26-282 °C.)	0.2
Weight, lb. per cu. ft	100	Volatilization point, °C	3,500
Porosity, per cent	25	Max. safe temp., oxid. conditions, °C	350
Tensile strength, lb. per sq. in	600	Ash, per cent	1.00-1.20
Crushing strength, lb. per sq. in., approx	4,000	Melting point under high pressure, °C	4,400 (?)*
Transverse strength, lb. per sq. in	1,000-1,500	Specific electric resistance, per in. cube	0.0042-0.0017
Therm. conductivity, cal. per sq. cm. per °C	0.00786	Machining qualities	Good

* Not known; sublimes without melting at atmosphere pressure.

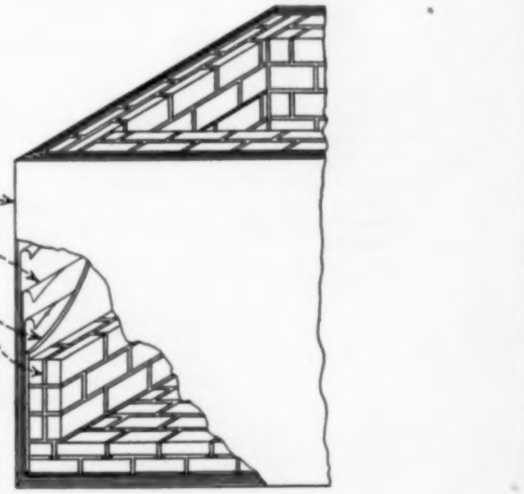


Plan of Both Layers of Floor Showing Carbon Spacers

Showing two methods of tank lining with carbon brick laid up in poured carbonaceous sulphur cement; the preferred form, at right, takes care of seepage by use of a resistant diaphragm.



Section Through Walls Showing Carbon Spacers



Makers of Structural Carbon and Graphite Products

MANUFACTURER (Name and Address)	Products	MANUFACTURER (Name and Address)	Products
Acheson Graphite Corp., New York, N. Y.	Graphite electrodes	Pure Carbon Co., St. Mary's, Pa.	Carbon and graphite electrodes
The Exolon Co., Blasdell, N. Y.	Graphite electrodes	Republic Carbon Co., Niagara Falls, N. Y.	Carbon electrodes
International Graphite & Electrode Corp., St. Mary's, Pa.	Graphite electrodes	Speer Carbon Co., St. Mary's, Pa.	Carbon and graphite brick, plates, blocks, tubes, cylinders, bushings, shapes
National Carbon Co., Cleveland, Ohio	Carbon and graphite brick, tile, tower packing, tubes, pipe, special shapes, electrodes	Stackpole Carbon Co., St. Mary's, Pa.	Various carbon and graphite products

Chemical Stoneware

CHEMICAL STONEWARE is a material which, if secured from a reputable maker, can be relied on to resist successfully any corrosive agent with the exception of hydrofluoric acid. It is proof against attack throughout the entire body, its resistance not depending upon a surface film. Recent improvements have made a wide range of bodies available, so that any desired physical property can be emphasized. Thus, the former disadvantage of low thermal conductivity has been largely corrected, and bodies highly resistant to thermal shock are available. Through improved mixtures and better technique, notably deairing, equipment of much thinner section, with lower weight and higher heat transmission is now made.

The adjoining view shows an installation of General Ceramics chemical stoneware equipment in the mustard plant of Charles Gulden, Inc., New York.

Physical Properties of Chemical Stoneware

The accompanying table, which has been prepared for us by the General Ceramics Co., gives the range of physical properties that is ordinarily encountered in chemical stoneware. It should be emphasized here that "chemical stoneware" is not the name of a definite material, such as an alloy, but a generic term applied to a wide variety of ceramic compositions, and hence that in any particular composition designed to give optimum properties in one respect, it will ordinarily be impossible to secure optimum properties in all other respects.

Specific gravity	2.2	Modulus of elasticity, lb. per sq. in.	$3\text{–}13\times10$
Tensile strength, lb. per sq. in.	1,000–7,500	Specific heat	0.185–0.2
Compressive strength, lb. per sq. in.	24,000–116,500	Thermal conductivity, B.t.u. per hr., sq. ft., °F., ft.	0.5–2.64
Bending strength, lb. per sq. in.	5,900–13,950	Linear expansion, per °F.	$0\ 083\text{–}3.4\times10^{-6}$
Modulus of rupture, lb. per sq. in.	4,000–14,000	Water absorption, per cent	0 0–4.5

WHO MAKES ACIDPROOF BRICK AND CHEMICAL STONEWARE

MANUFACTURER (Name and Address)	Materials
Buckeye Pottery Co., Macomb, Ill.	Acidproof ceramics
Champion Porcelain Co., Detroit, Mich.	Special porcelain shapes, impellers, nozzles, etc.
Corhart Refractories Co., Louisville, Ky.	Acidproof brick
Alphons Custodis Chimney Const. Co., New York, N. Y.	Acidproof brick construction, towers, tanks
Electro-Chemical Supply & Engineering Co., Paoli, Pa.	Acidproof brick and masonry construction
General Ceramics Co., New York, N. Y.	Chemical stoneware of all types
B. Mifflin Hood Co., Daisy, Tenn.	Acidproof tower packings and flooring tiles
Maurice A. Knight, Akron, Ohio	Chemical stoneware of all types
Patterson Foundry & Machine Co., East Liverpool, Ohio	Acidproof lining blocks and grinding balls
Quigley Co., New York, N. Y.	Acidproof brick
Robinson Clay Product Co. of N. Y., New York, N. Y.	Acidproof and vitrified sewer tile
United States Stoneware Co., Akron, Ohio	Chemical stoneware of all types

WHO MAKES CEMENTS AND PUTTIES FOR BRICK AND STONEWARE

MANUFACTURER (Name and Address)	Trade Names	Compositions, Applications, Types
Anti-Hydro Waterproofing Co., Newark, N. J.	Anti-Hydro	Water-, acid-, alkali-, oil-resisting concrete mix
Atlas Mineral Products Co., Mertztown, Pa.	Tegul-Vitrobond, -Tileset, -Mineralead	Thiokol-containing sulphur-base cements for tanks, floors, pipe
Charlotte Chemical Labs., Charlotte, N. C.	Charlab, Acipruf, Carolina	Standard and chemical-setting silicate cements; acidproof putty
Alphons Custodis Chimney Const. Co., New York, N. Y.	Penchlor, Asplit	See Pen-Chlor, Inc.
Electro-Chemical Supply & Engineering Co., Paoli, Pa.	Duro Standard, Special, Triple X	Silicate cements for all acid conditions; also water and steam
General Ceramics Co., New York, N. Y.	Acidproof Nos. 1, 6, 7, 8	Silicate cements and linseed oil- and asphalt-base putties
B. F. Goodrich Rubber Co., Akron, Ohio	Plastikon	Rubber-base putty
The Haveg Corp., Newark, Del.	Havegit 41, 43	Self-hardening phenolic resin cements for acids
Maurice A. Knight, Akron, Ohio	Knight	Silicate cements for strong acids
Nuken Products Co., New York, N. Y.	Basolit	Sulphur-base cement for acids
Patterson Foundry & Machine Co., East Liverpool, Ohio	Porox Cement	Silicate cement for strong acids
Pecora Paint Co., Philadelphia, Pa.	Acitite, Acichlor, Cushion Putty	Slow- and quick-drying cements and elastic putties for acids
Pen-Chlor, Inc., Philadelphia, Pa.	Penchlor, Asplit	Chemical-setting silicate cement; self-hardening resin cement
Philadelphia Quartz Co., Philadelphia, Pa.	"S" Brand Sodium Silicate	1:3.86 ratio sodium silicate for acidproof cements
Quigley Co., New York, N. Y.	Acidproof Nos. 1 and 2	Silicate cements for acid gases and mineral acids
H. H. Robertson Co., Pittsburgh, Pa.	Asphaltic Fibre Putty	Caulking compound for general resistance
The Sullivan Co., Memphis, Tenn.	Acidol, Sulsilo	Pouring cements and pre-mixed silicate cements for strong acids
Technical Products Co., Pittsburgh, Pa.	Insa-Lute, Acidproof	Standard and quick-setting silicate cements, etc.
United States Stoneware Co., Akron, Ohio	U. S. Standard, Pre-Mixt, Calktite and others	Silicate cements of all types, resin cements, putties, etc.

Protective Coatings

NO FIELD of chemical industry has undergone greater change in recent years than is to be seen in the development of protective coatings. With the advent and greatly broadened use of synthetic resins there has been a practical revolution in paint technology. Greater knowledge of the mechanism of corrosion and its prevention through the use of both organic and inorganic inhibitors has stimulated progress in devising new means of protecting iron and steel equipment in chemical plants.

The basic pigment, red lead, is probably the oldest and most widely used of the so-called anti-corrosion or anti-rust paints. Sublimed blue lead is also popular as a rust inhibitor. More recently the chromates, particularly zinc chromate and basic lead chromate, have come into wide use as primers. Metallic paints prepared from aluminum, copper, bronze, and zinc powders are effective protection for many types of exposure.

But because caustic alkali, salt water and certain other corrosives soften paint by attacking its vehicle, some of the best protective coatings are composed of asphalt or bitumen bases dissolved in suitable thinners. These dry by evaporation rather than by oxidation, leaving a tough, leathery, flexible film resistant to abrasion as well as to corrosion. The natural asphalts, such as gilsonite, elaterite and wurtzilite, are often used in such paints.

Quick drying solutions of hydrocarbons derived from crepe rubber give unusually satisfactory acid and alkali resisting finishes for the protection not only of metal but of concrete and wood surfaces as well. An interesting application in the use of this rubber-base paint is on the inside of steel tankcars delivering iron-free caustic soda solution of 50 per cent concentration for the rayon industry.

When chlorinated rubbers, such as Tornesit, are combined with plasticizers and in some cases with pigments and resins, coating materials of remarkable properties have been developed. One of these is Tornalac, which is being used to protect process equipment against corrosion as is shown in the accompanying illustration of a battery of cylindrical tanks in a chemical plant exposed to sulphuric and nitric acid vapors.

PROTECTIVE PAINT COATINGS RECOMMENDED FOR CORROSION RESISTANCE

Trade Name of Product	*Manufacturer*
AAA No. 20	Quigley Co., Inc., New York, N. Y.
Alcoa Albron	Aluminum Co. of America, Pittsburgh, Pa.
Aquatite	The Aquatite Co., N. Hollywood, Calif.
Asphalt Emulsion	The Flintkote Co., New York, N. Y.
Bakelite Iron Oxide	The Akron Varnish Co., Akron, Ohio
Bakelite Synthetic Resins	Bakelite Corporation, New York, N. Y.
Bar Ox No. 97	The Truscon Laboratories, Detroit, Mich.
Barrett Pipe Coatings	Pipe Coating Dept., The Barrett Co., New York, N. Y.
Berryloid Zinc Chromate Primer	Berry Bros., Detroit, Mich.
Bitumastic Enamels	Wailes Dove-Hermiston Corp., Cleveland, Ohio
Biturine	General Paint Corp., (Hill-Hubbell Division), Chicago, Ill.
Black 904	Brevolite Lacquer Co., No. Chicago, Ill.
Bonderite	Parker Rust Proofing Co., Detroit, Mich.
Briggs Bitumen	W. A. Briggs Bitumen Co., Philadelphia, Pa.
Bronzing Mixture	The Ault & Wiborg Varnish Works, Cincinnati, Ohio
Calba-Gray	Calbar Paint & Varnish Co., Philadelphia, Pa.
Carbo-lastic	The J. E. Harris Co., Wooster, Ohio
Chromate Metal Primer 702	E. I. duPont de Nemours & Co., Philadelphia, Pa.
Chromate Primer 1525	Certain-teed Products Corp., St. Louis, Mo.
Conwax	The Aquatite Co., N. Hollywood, Calif.
Coppercote	American Coppercote, Inc., New York, N. Y.
Cromodine	American Chemical Paint Co., Ambler, Ohio
Custodis Kabe Membranes	Custodis Construction Co., New York, N. Y.
Dairy White	Sleight Bituminous Products Co., Baltimore, Md.
D.B.R.L.	National Lead & Oil Co., Pittsburgh, Pa.
Gray # 335 Synthetic Resin	Chas. R. Long Co., Louisville, Kentucky
Hercose C	Hercules Powder Co., Wilmington, Del.
Impervite	Slingle-Gibb Corp., Newark, N. J.
Impervobond Black	James B. Sipe & Co., Pittsburgh, Pa.
Inertol	The Inertol Co., New York, N. Y.
Luminall	National Chemical & Mfg. Co., Chicago, Ill.
Luminex	Jamestown Paint & Varnish Co., Jamestown, Pa.
Luster-Kote 10	Luster-Kote Inc., Struthers, Ohio
Mabelite	Eastern Mabelite Corp., New York, N. Y.
Metalastic	The Sherwin-Williams Co., Cleveland, Ohio
Permite Resalum	Aluminum Industries, Inc., Cincinnati, Ohio
Petro-Seal, S. W.	The Sherwin-Williams Co., Cleveland, Ohio
Plicote	The Watson-Standard Co., Pittsburgh, Pa.
Pliolite	The Goodyear Tire & Rubber Co., Akron, Ohio
P. P. G. Aluminum Mix	Pittsburgh Plate Glass Co., Newark, N. J.
Primer 81131	Samuel H. French Paint Co., Philadelphia, Pa.
Red Primer No. 825	Industrial Paint Co., Haysville, Pa.
Relpaco	Reliance Paint Co., Brooklyn, N. Y.
Rubalt	Alfred Hague & Co., New York, N. Y.
Saverite	National Rust Prevention and Waterproofing Co., Los Angeles, Calif.
S. D. O.	Organic Chemicals Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.
Solvay Hydraulic	Semet Solvay Co., New York, N. Y.
S. R. P. Coatings	L. Sonneborn Sons, New York, N. Y.
S-W G & G Primer	The Sherwin-Williams Co., Cleveland, Ohio
S-W Kromik Metal Primer	The Sherwin-Williams Co., Cleveland, Ohio
Tank Primer Red	The Lowe Brothers Co., Dayton, Ohio
Tiger Black	W. W. Lawrence & Co., Pittsburgh, Pa.
Tornalac	Paper Makers Chemical Co., Kalamazoo, Mich.
Tornesit	Hercules Powder Co., Wilmington, Del.
Triple Leadkote	E. & F. King & Co., Boston, Mass.
Wipe-On	Wipe-On Corp., New York, N. Y.
Wurtzilite	American Wurtzilite Co., Chicago, Ill.
Zinc Dust Base	New Jersey Zinc Co., New York, N. Y.

Glass, Glass-Lined and Fused Silica

THE glassy materials, which include acid-resisting glass enamels for steel and cast iron, fused silica and quartz, and borosilicate glass (Pyrex), are highly resistant to a wide range of corrosive agents, including all acids with the exception of hydrofluoric. Chromic and phosphoric acids have some effect but this is not generally considered a serious deterrent. The caustic alkalis have a more severe action which generally precludes use.

Glass-lined equipment is now produced in many forms, including tanks, kettles, stills, condensers, pans, vacuum pans, evaporators, mixers, percolators, pipe, valves and fittings. Fused silica, more difficult to fabricate, is produced in a smaller number of simpler forms. Glass equipment, still relatively new, is available in the form of pipe, valves, fittings, heat exchangers, distilling columns, trays and bubble caps.

PHYSICAL PROPERTIES OF BOROSILICATE GLASS, FUSED QUARTZ AND SILICA

MATERIAL	Specific Gravity	Specific Volume, Cu. in. per lb.	Tensile Strength, Lb. per sq. in.	Modulus of Elasticity, Lb. per sq. in. x 10^{-5}	Hardness*	Thermal Expansion, Per °F. x 10^4	Thermal Conductivity, Cal. per sec., cm., °C. x 10^4	Specific Heat, Cal. per °C., gm.	Softening Point, °F.	Breakdown Voltage, 60 cycles, v. per mil	Dielectric Constant, 60 cycles	Refractive Index, N_D	Thickness, 1/1000 in.	Transparency†	Forms Available**
Borosilicate glass	2.24	12.3	10,000	93	3	0.32	27	0.20	1,290	1,400 (0.1 in.)	4.86	1.47	10 up	T, TL	S, R, T, forms
Fused quartz	2.20	12.6	7,000	105–126	4.9	0.049	23.7	....	2,600	410 (¼ in.)	3.7	1.459	1 up	T	S, R, T, forms
Fused silica	2.07–2.1	13.4	7,000	94–114	....	0.053–0.059	19–20	....	2,600–2,700	436 (¼ in.)	3.7	....	5 up	TL, O	S, R, T, forms

* Hardness: 2.5 mm. ball, 25 kg. load, depth in 1/200 mm.
† T = transparent; TL = translucent; O = opaque.
** S = sheets; R = rods; T = tubes.

Chemical Resistance of Borosilicate Glass, Glass-Lined Steel and Fused Silica

These materials satisfactorily resist many chemicals, including the following:*

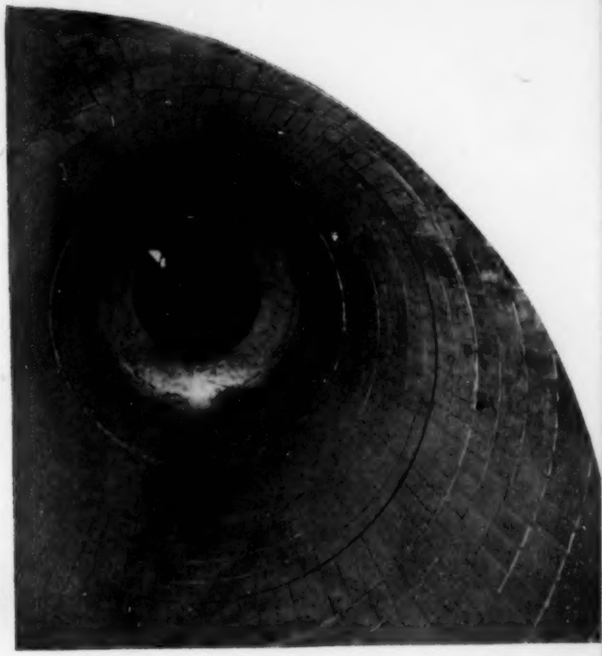
Acetic acid
Acetic anhydride
Acetone
Aluminum chloride
Aluminum sulphate
Ammonium chloride
Ammonium nitrate
Ammonium sulphate
Amyl acetate
Amyl chloride
Aniline
Benzaldehyde
Bromine
Butyl acetate
Calcium chloride
Carbon bisulphide
Carbon tetrachloride
Carbonic acid
Chloracetic acid
Chlorine water
Citric acid
Copper sulphate
Ethyl acetate
Fatty acids
Ferric chloride
Ferrous chloride
Ferrous sulphate
Formaldehyde
Formic acid
Hydrobromic acid
Hydrochloric acid
Hydrogen peroxide
Iodine
Lactic acid
Magnesium chloride
Magnesium sulphate
Mixed acid
Nitric acid
Nitrous acid
Oxalic acid
Phenol
Sea water
Sodium bisulphate
Sodium bisulphite
Sodium nitrate
Sodium sulphite
Sulphuric acid
Sulphurous acid
Tannic acid
Hot gases†
- Chlorine
- Hydrocarbons
- Nitrogen oxides
- Sulphur dioxide
- Sulphur trioxide

* Following is a group of chemicals which may be handled in construction materials of this class according to some but not all of the makers of such equipment: anhydrous ammonia ammonium hydroxide, calcium hypochlorite, chromic acid, phosphoric acid, sodium ferricyanide, hydrosulphite, hypochlorite, phosphate and sulphide.
† Below 500°C. for glass and 300°C. for glass-lined.

WHO MAKES GLASS, GLASS-LINED AND FUSED SILICA EQUIPMENT

Trade Names	MANUFACTURER (Name and Address)	Composition, Forms Available
Alsop	Alsop Engineering Co., New York N. Y.	Glass-lined steel tanks and mixers
Amersil	Amersil Corp., Hillside, N. J.	Fused silica ware such as pans, pipes, gas coolers, absorbers
Fused Quartz	General Electric Co., Schenectady, N. Y.	Transparent fused quartz in various small sized articles
Fused Quartz	Hanovia Chemical & Mfg. Co., Newark, N. J.	Transparent fused quartz in various small sized articles
Glascote	Glascote Co., Euclid, Ohio	Glass-enameled steel equipment
Pfaudler	The Pfaudler Co., Rochester, N. Y.	Wide variety of standard and special glass-enameled steel equipment — various formulas
Pyrex	Corning Glass Works, Corning, N. Y.	Special heat- and corrosion-resisting borosilicate glass supplied in various forms: pipe, columns, etc.
Vitreosil	The Thermal Syndicate, Brooklyn, N. Y.	Fused silica (non-transparent) supplied in various large forms; fused quartz (transparent) in smaller sizes

Refractories



MANY DEVELOPMENTS have taken place in the refractories industry in the last decade, both on account of the discovery of new sources for the better raw materials, and because of the enhanced understanding of refractory properties that has come from the industry's extensive research. Nevertheless, firebrick, still takes care of the bulk of applications.

Firebrick, itself, has been much improved and other newer forms include the higher alumina varieties from diaspore, kaolin and bauxite, the mullite types from andalusite, cyanite and sillimanite, the light-weight insulating refractories, and the unfired Ritex type (General Refractories Co.) shown in the accompanying illustration. The last, one of the newest developments, is made in chemically bonded chrome and magnesite, employing special sizing technique and super-pressures in pressing.

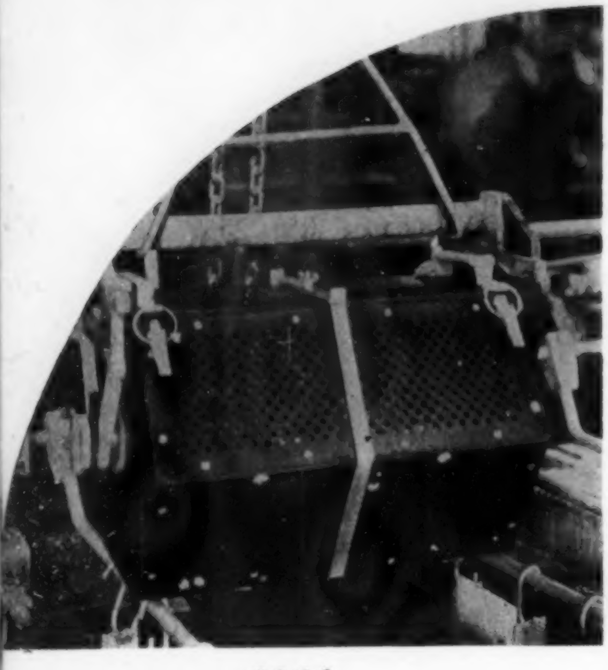
PHYSICAL PROPERTIES OF REFRACTORY MATERIALS*

Type of Brick	Chrome	No. 1 Fire Clay	Fused Alumina	Fused Refractory	Kaolin	Kaolin Ins. Refr.	Magnesite	Mullite Refractory	Silica	Silicon Carbide	Unburned Magnesite
Typical composition, per cent	44 Cr_2O_3 16 FeO 15 MgO 15 Al_2O_3 5 SiO_2	42 Al_2O_3 54 SiO_2 2 Flux	90 Al_2O_3 7 SiO_2 3 Flux	75 Al_2O_3 20 SiO_2 3.3 TiO_2	45 Al_2O_3 52 SiO_2 1 Flux	45 Al_2O_3 52 SiO_2 1 Flux	85 MgO 7 Fe_2O_3 3 CaO 3 SiO_2	52 Al_2O_3 44 SiO_2 2.5 Flux	96 SiO_2	100 SiC	7 Al_2O_3 7 Cr_2O_3 69 MgO 6 Fe_2O_3 4 CaO 7 SiO_2
Fusion point, °F.	4,000	3,050	3,500	3,360	3,200	3,200	4,000	3,300	3,050	4,000†	4,000
Load resist., temp. °F. for 10% shrink, 25 lb.	2,600	2,700	2,800		2,900		2,500	3,000	3,000	3,100	
Resistance to spalling, cycles	2	20	4		20		1	25	None	25	5
Wt. per brick (std. 9 in.), lb.	11.1	7.5	10	10	7.5	1.8	10	7.0	6.5	9	10.4
Porosity, per cent		20-30	20	0.4	20	80		25	20-30	18	15
Specific heat (60-1,200 °F.)	0.20	0.23	0.20	0.23-0.255	0.23	0.23	0.27	0.23	0.23	0.20	
Relative slag resistance											
Acid steel slag	Poor	Fair	Good		Fair	Poor	Fair	Good	Good	Good	Good
Basic steel slag	Good	Poor	Good		Poor	Poor	Good	Fair	Poor	Good	Good
Mill scale	Good	Poor	Fair		Poor	Poor	Good	Fair	Poor	Fair	Good
Coal ash slag	Fair	Fair	Good		Fair	Poor	Good	Fair	Fair	Good	Fair

* Revision of tabulation from *Chem. & Met.*, Apr., 1932, with additional information on newer refractories. † Decomposed.

WHO MAKES REFRACTORIES AND HIGH TEMPERATURE MORTARS

MANUFACTURER (Name and Address)	Principal Types
Babcock & Wilcox Co., New York, N. Y.	Glass plant refrs., h.t. mortars, plastic refrs., insulating and kaolin refrs.
Bartley Crucible & Refr. Co., Trenton, N. J.	Graphite crucibles, firebrick, magnesite refrs.
Botfield Refractories Co., Philadelphia, Pa.	Chrome, firebrick, plastic refrs., h.t. mortars.
Carborundum Co., Perth Amboy, N. J.	Silicon carbide and aluminum oxide refrs. and h.t. mortars.
Champion Spark Plug Co., Detroit, Mich.	Sillimanite plastic refrs., electric furnace refrs.
Corhart Refractories Co., Louisville, Ky.	H.t. mortars, electro-cast mullite refrs.
Corundite Refractories, Inc., Massillon, Ohio.	Firebrick, h.t. mortars, plastic refrs., alumina, silica and mullite refrs.
Denver Fire Clay Co., Denver, Colo.	Firebrick,h.t. mortars, plastic refrs.,fireclays.
Joseph Dixon Crucible Co., Jersey City, N. J.	Graphite crucibles.
Ehret Magnesia Mfg. Co., Valley Forge, Pa.	H.t. mortar.
Emsco Refractories Co., Vernon, Calif.	Firebrick, glass plant refrs., h.t. mortars.
General Refractories Co., Philadelphia, Pa.	Fired and unfired chrome and magnesite, firebrick, h.t. mortars, plastic and silica.
A. P. Green Fire Brick Co., Mexico, Mo.	Firebrick, h.t. mortars, plastic refrs., fireclays.
Harbison-Walker Refrs. Co., Pittsburgh, Pa.	Firebrick, h.t. mortars, silica, various basic and special refrs.
Illinois Clay Products Co., Goose Lake, Ill.	Firebrick, h.t. mortars, insulating cements, coatings and brick.
Johns-Manville, New York, N. Y	H.t. mortars and plastic refrs.
Laclede-Christy Clay Prod. Co., St. Louis, Mo.	Firebrick, h.t. mortars, plastic refrs., glass plant refrs., fireclays.
E. J. Lavino & Co., Philadelphia, Pa.	Chrome and magnesite refrs., h.t. mortars, silica refrs., fireclays.
Massillon Refractories Co., Massillon, Ohio.	Firebrick, h.t. mortars, plastic refrs., special compositions.
McLeod & Henry Co., Troy, N. Y.	Firebrick, h.t. mortars, plastic refrs., fireclays.
Mullite Refractories Co., Shelton, Conn.	H.t. mortars, plastic refrs., mullite refrs.
National Carbon Co., Cleveland, Ohio.	Carbon refrs.
North American Refrs. Co., Cleveland, Ohio.	Firebrick, h.t. mortars, plastic and silica refrs., fireclays.
Norton Co., Worcester, Mass.	H.t. mortars, silicon carbide and fused alumina refrs.
George F. Pettinos, Inc., Philadelphia, Pa.	H.t. mortars, fireclays.
Quigley Co., Inc., New York, N. Y.	Firebrick, insulating refrs., super firebrick, h.t. mortars, plastic refrs.
Seaboard Refrs. Co., Perth Amboy, N. J.	Firebrick, h.t. mortars, plastic and insulating refrs., silicon carbide and mullite refrs.
Vitrefrax Corp., Los Angeles, Calif.	Glass plant refrs., firebrick, h.t. mortars, plastic refrs., fireclays.



Plastics

AMONG the most important types of plastic products are the phenolic, urea, vinyl, cellulose nitrate, cellulose acetate, ethyl cellulose, and soybean. Phenolic resinoid is available in almost any shape or size required, both in molded and in laminated products. Large pieces of equipment made of this material, which is tough, nonabsorbent and easily machined, are now in use for tanks, kettles, stills, and the like. This resin has been satisfactorily used for handling many acids, salts and solvents. (See tabulation below.) It may be used at temperatures up to 130 deg. C. and is not affected by rapid temperature changes.

Urea-formaldehyde resin, without filler, is clear. Freedom from odor commends it for uses to which phenolic resinoids are not applicable. Its resistance to water is now very nearly equal to that of the phenolic type. It is not appreciably attacked by mineral or vegetable oils, and is unaffected by alcohol, acetone and other common solvents. This resin is quite resistant to cold, dilute alkalis and hot, very dilute alkalis, such as soap and borax.

Vinyl resin is transparent, nonflammable and odorless. Its coefficients of expansion and water absorption are low and it is insoluble in alcohols. It may be extruded in the form of rods, tubes or sheets, stamped into various forms and molded into large objects.

Among cellulose plastics are three groups: cellulose nitrate and acetate and ethyl cellulose. The nitrate has been used to some extent for process industry equipment but, because of its flammability, this type of application is somewhat limited. The acetate is not flammable and is unaffected by contact with vegetable and mineral oils, although essential oils and alcohols are partial solvents. This material is not satisfactory for handling acids or alkalis of strength in excess of 0.5 per cent. Ethyl cellulose, which is also non-flammable, softens at temperatures slightly over 100 deg. C., has excellent resistance to alkalis and is likewise resistant to decomposition by dilute acids. The material is stable to heat and not discolored by sunlight.

Soybean plastics, as made by the Ford Motor Co., contain in addition to casein-formaldehyde resin a certain amount of phenol which results in a waterproof and durable product. At present, applications are confined to parts for motor cars.

Resistance of Haveg to Certain Chemical Agents*

Haveg 41 Is Resistant to

Acetic acid	Chlorine	Hydrobromic acid	Oils	Sodium peroxide
Alcohol	Chlorine water	Hydrocarbons	Oxalates	Sodium silicate
Aluminum salts	Chloride of lime	Hydrochloric acid	Oxalic acid	Sodium sulphide
Ammonia	Copper sulphate	Hydrogen peroxide	Paraffin	Sulphur, molten
Ammonium sulphate	Ethylene chlorhydrin	Hydrogen sulphide	Petroleum	Sulphur chloride
Aniline salts	Fatty acids	Lactic acid	Phosphates	Sulphuric acid, to 50%
Calcium chloride	Ferric chloride	Magnesium chloride	Phosphoric acid	Sulphurous acid
Calcium hypochlorite	Ferrous chloride	Manganese sulphate	Potassium carbonate	Tannic acid
Carbon tetrachloride	Ferrous am. chloride	Milk of lime	Potassium iodide	Tartaric acid
Caustic lime	Formic acid, to 40%	Neut. soap sols.	Sodium carbonate	Zinc chloride

Haveg 43 Is Resistant to

Fluorides	Fluosilicates	Fluosilicic acid	Hydrofluoric acid	H F mixtures

Haveg Is Not Resistant to

Acetone	Nitric acid	Potassium hydroxide	Sodium hydroxide	Sodium hypochlorite
Conc. chromic acid	Organic bases			H_2SO_4, hot, conc.

* Based on a tabulation of the Haveg Corp.

MECHANICAL AND PHYSICAL PROPERTIES OF PLASTIC MATERIALS

Material	Form	Specific Gravity	Softening Point, °F.	Thermal Expansion x 10⁵ per °C.	Thermal Conductivity x 10⁴ cal. per sec. cm. °C.	Specific Heat, C. G. S.	Tensile Strength, Lb. per sq. in.	Elongation, %	Electrical Resistivity (vol.), 30° C., 10¹⁰ ohm cm.	Burning Rate*	Effect of Heat	Effect of Light	Effect of Aging	Effect of Water: Cold	Effect of Water: Hot	Machining Qualities
Phenolic Resinoids	Pure hardened resinoid	1.2 to 1.3			3 to 4	0.33 to 0.36	8-in. test piece 5,000 to 11,000		1 to 1,000	E.L.	Withstands 250 °F. with some hardening	Slight by ultra-violet	None			Good
	Molded with wood flour filler	1.3 to 1.4			4 to 6	0.30 to 0.40	A. S. T. M. Test 6,000 to 12,000		1 to 100	E.L.	Withstands 250 °F. with some hardening	Slight by ultra-violet	None	None		Good

Material	Form	Specific Gravity	Softening Point, °F.	Thermal Expansion x 10^6 per °C.	Thermal Conductivity x 10^4 cal. per sec. cm. °C.	Specific Heat, C. G. S.	Tensile Strength Lb. per sq. in.	Elongation, %	Electrical Resistivity (vol.), 30° C., 10^{10} ohm cm.	Burning Rate*	Effect of Heat	Effect of Light	Effect of Aging	Effect of Water		Machining Qualities
														Cold	Hot	
Phenolic Resinoids	Molded with fabric filler	1.3 to 1.4			4 to 6	0.30 to 0.40	A. S. T. M. Test 4,500 to 9,000		0.1 to 10	E.L.	Withstands 250 °F. with some hardening	Slight by ultra-violet	Improved			Fair
	Molded with asbestos filler	1.8 to 2.0			12 to 20	0.30 to 0.40	A. S. T. M. Test 5,000 to 10,000		0.01–1.0, mica filler, 10–1,000	P.I.	Withstands 375 to 475 °F.	Slight by ultra-violet	Improved	Very resistant		Fair
	Laminated with paper filler	1.3 to 1.4		2	5 to 8	0.30 to 0.40	6,000 to 20,000		1 to 100	E.L.	Withstands 250 °F. with some hardening	Slight by ultra-violet	Improved	Slight on long immersion	More rapid	Good
	Laminated with fabric filler	1.3 to 1.4		2	5 to 8	0.30 to 0.40	8,000 to 12,000		0.1 to 1.0	E.L.	Withstands 250 °F. with some hardening	Slight by ultra-violet	Improved	Slight on long immersion	More rapid	Good
Urea-Formaldehyde Resinoid	Molding plastic	1.48 to 1.50					8,000 to 13,000		2,800	E.L.	Slight	None	None	None	None up to 30 min. boiling	Fair
Cellulose Nitrate	Plastic	1.35 to 1.60	160 to 195	12 to 16	3.1 to 5.1	0.34 to 0.38	4,000 to 10,000	5 to 30	0.106 to 0.32	V.H.	Decomposes at 100 to 150 °C.	Becomes brittle	None	Slight swelling	Slight swelling	Good
Cellulose Acetate	Plastic	1.27 to 1.31	115 to 160		5.4 to 6.3		5,400	13	0.30	L.	More stable than cellulose nitrate	More stable than nitrate	None	Slight swelling	Attacked	Good
	Press powder	1.30 to 1.63	162 to 300	14 to 16	5.3 to 8.7		1,800 to 3,200	0.2 to 0.5	6.2	L.	More stable than cellulose nitrate	More stable than nitrate	None	Slight swelling	Attacked	Good
Vinyl Resin	Filled	1.2 to 2.5	160				7,000		>10	Nil	Darkens at 150 °C.		None	None	Softens	Good
	Unfilled	1.23	150				9,000		>10,000	Nil	Darkens at 150 °C.		None	None	Softens	Good
Depolymerized Colloidal Resin	Sheets or plastics		350 to 600		Low		300 at 70° F.				Softens		None			

* E. L., extremely low; P. I., practically incombustible: V. H., very high; L, low

WHO MAKES MOLDING POWDERS AND OTHER PLASTIC MATERALS

MATERIAL	MANUFACTURER (Name and Address)	Type of Plastic	Forms Available
Bakelite	Bakelite Corp., Bloomfield, N. J.	Phenolic resinoid	Molding powder, soluble resins
Beetleware	American Cyanamid & Chemical Co., New York, N. Y.	Urea resinoid	Molding powder
Catalin	American Catalin Corp., New York, N. Y.	Cast phenolic	Sheets, rods, tubes
Celoron	Continental Diamond Fibre Co., Newark, Del.	Phenolic resinoid	Molding powder, sheets, rods, tubes
Cetex	General Electric Co., Schenectady, N. Y.	Cold-molded plastic	Molded forms
Dilecto	Continental Diamond Fibre Co., Newark, Del.	Phenolic resinoid	Sheets, rods, tubes, molded forms
Durez	General Plastics, Inc., N. Tonawanda, N. Y.	Phenolic resinoid	Molding powder, soluble, special
Durite	Stokes & Smith Co., Philadelphia, Pa.	Phenolic resinoid	Molding powder, laminated
Ethyl Cellulose	Hercules Powder Co., Wilmington, Del.	Cellulose ether	Granular powder
Formica	Formica Insulation Co., Cincinnati, Ohio	Phenolic resinoid	Laminated
Haveg	Haveg Corp., Newark, Del.	Phenolic resinoid	Chemical equipment
Indur	Reilly Tar & Chemical Co., Indianapolis, Ind.	Phenolic resinoid	Molding powder
Lamicoid	Mica Insulator Co., New York, N. Y.	Laminated products	Laminated
Micanite	Mica Insulator Co., New York, N. Y.	Laminated products	Laminated
Lumarith	Celluloid Corp., Newark, N. J.	Cellulose acetate	Molding powder
Micarta	Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.	Phenolic resinoid	Laminated
Phenolite	Natl. Vulcanized Fibre Co., Wilmington, Del.	Phenolic resinoid	Laminated
Plastacele	Du Pont Viscoloid Co., Arlington, N. J.	Cellulose acetate	Molding powder, sheets, rods, tubes
Plaskon	Plaskon Co., Toledo, Ohio	Urea resinoid	Molding powder
Pyralin	Du Pont Viscoloid Co., Arlington, N. J.	Cellulose nitrate	Sheets, rods, tubes
Pyroflex	Maurice A. Knight, Akron, Ohio	Depolymerized colloidal resin	Sheets, bulk
Resinox	Resinox Corp., New York, N. Y.	Phenolic resinoid	Molding powder, soluble resins
Resoglaz	Advance Solvents & Chem. Co., New York, N. Y	Styrol resinoid	Molding powder
Spauldite	Spaulding Fibre Co., Tonawanda, N. Y.	Phenolic resinoid	Laminated
Synthane	Synthane Corp., Oaks, Pa.	Phenolic resinoid	Laminated
Tenite	Tennessee Eastman Corp., Kingsport, Tenn.	Cellulose acetate	Molding powder
Textolite	General Electric Co., Schenectady, N. Y.	Phenolic resinoid	Molding powder, laminated
Unyte	Plaskon Co., Toledo, Ohio	Urea resinoid	Molding powder
Victron	Naugatuck Chemical Co., New York, N. Y.	Styrol resinoid	Molding powder
Vinylite	Carbide & Carbon Chem. Co., New York, N. Y.	Vinyl resinoid	Molding powder

Rubber and Like Products

NATURAL RUBBER has been used for the construction of chemical engineering equipment for many years. More recently several rubber-like products have been developed and are now available for services where their special characteristics justify the greater cost.

Rubber may be molded into any form desired and it may be satisfactorily bonded to structural materials. Rubber compounds are designed for special purposes which should be specified when ordering. This is necessary as no one type is applicable for all conditions if maximum benefits are to be expected. For example, linings range in characteristics from a soft, pure gum, non-contaminating lining to flexible hard rubber. Again, it may be desired to emphasize abrasion resistance as in the fuel downcomers shown in the accompanying illustration.

In the case of metallic equipment of irregular shapes, adherent protective coatings of soft or hard rubber are readily applied by the anode process. Remarkably high tear resistance is characteristic of anode rubber. Its excellent corrosion resistance may be used to advantage when rubber coatings are applied to such articles as plating racks, dipping baskets, screens, floats, stirrers and the like.

Among the rubber-like materials are Duprene, Thiokol, Plioform and Koroseal. Duprene, the properties of which are described below, is much more resistant than natural rubber to the swelling action of hydrocarbons. Thiokol likewise resists petroleum products and volatile solvents. Distilled water as well as dilute or concentrated salt solutions are not harmful to it, while acetic acid gives no trouble. However, it is not recommended for use with a 20 per cent caustic soda solution, or with concentrated ammonia.

Plioform is notable for its resistance to moisture and various chemicals, and its low specific gravity. Since this material contains no sulphur, yet is a rubber derivative, it is able to replace hard rubber in certain chemical uses.

Koroseal is made in a variety of compounds ranging from bone-like hardness to liquid. Its useful temperature range is from —15 deg. F. upward to about 150 deg. It is resistant to sunlight and shows high resistance to oxidation. It is superior to rubber in respect to water absorption and resists swelling and disintegration in presence of vegetable and mineral oils.

Chemical Resistance of Duprene

Owing to the fact that various compounding ingredients must be mixed with Duprene to develop its desirable properties, it is difficult to state in the absence of actual service tests against which materials any Duprene composition is resistant. Consequently, the manufacturers prefer to work with users in running tests and developing the most appropriate compounds to meet individual problems. Below are listed the general properties of Duprene compositions.

Animal, Vegetable, Petroleum Products. When it is contact with waxes, greases, oils, kerosene, gasoline, and the other higher petroleum fractions, Duprene swells slightly but largely retains its strength, resiliency and rubber-like properties. It is not dissolved, does not become tender and does not slough off small particles. Less highly saturated compounds attack Duprene to a greater extent than the saturated ones.

Oxidizing Chemicals. Duprene is said to be very resistant to oxidation and to withstand natural and accelerated aging, resisting such chemicals as chlorine which forms a hard, protective film on the surface. It resists oxidizing acids in low concentrations.

Inorganic Chemicals. Such chemicals have little effect on Duprene although special compositions, proved under actual service conditions, are often advisable.

Organic Chemicals. Duprene resists the attack of most organic compounds, the more highly saturated compounds having less effect than the less saturated.

Duprene is not recommended for use with lacquer thinners, the chlorinated organic compounds, creosote, or concentrated nitric and sulphuric acids.

Chemical Resistance of Rubber Compounds and Koroseal

The following chemicals, at any concentration unless otherwise noted, are satisfactorily resisted by suitable compounds of both hard and soft rubber at temperatures up to 150 deg. F., and by both hard and soft Koroseal at temperature to 190 deg. F. Exceptions are to be noted in the footnotes. Additional chemicals are given in the supplementary table on page 561.

Acetone [1]	Carbonic acid	Ferrous sulphate	Phosphoric acid to 85 per cent	Na or K hypochlorite
Alums	Casein	Fluoboric acid	Plating solutions	Na or K sulphide
Aluminum chloride	Castor oil [2]	Fluosilicic acid	Potassium cuprocyanide	Na or K sulphite
Aluminum sulphate	Chromic acid [3]	Gallic acid	Potassium dichromate [1]	Na or K thiosulphate
Ammonium chloride	Citric acid [2]	Glucose	Potassium hydroxide	Sodium hydroxide
Ammonium sulphate	Coconut oil [2]	Glue	Propyl alcohol	Stannic chloride
Amyl alcohol	Copper chloride [2]	Glycerine	Silver nitrate [6]	Stannous chloride
Aniline hydrochloride	Copper cyanide [4]	Hydrochloric acid	Soaps	Sulphuric acid to 50 per cent
Arsenic acid	Copper sulphate	Hydrofluoric acid to 50 per cent	Na or K antimonate	Zinc chloride
Barium sulphide	Cottonseed oil [2]	Hydrogen sulph. water	Na or K acid sulph.	Zinc sulphate
Butyl alcohol	Dyestuffs [2]	Malic acid	Na or K bisulphite [4]	Tannic acid
Calcium bisulphite [2]	Ethyl alcohol	Methyl alcohol	Na or K chloride	Tartaric acid
Calcium chloride	Ethylene glycol	Nickel acetate [1]	Na or K cyanide	Triethanolamine
Calcium hypochlorite	Ferric chloride			

[1] Rubber only. [2] Koroseal hard or soft; hard rubber only. [3] Koroseal only. [4] In solution in alkali cyanides. [5] Koroseal hard or soft; soft rubber only. [6] Hard rubber and hard Koroseal only.

Chemical Resistance of Rubber Compounds and Koroseal (Continued)

The following tabulation covers chemicals which are resisted by rubber and Koroseal under less severe conditions, or only by a certain grade, or which for some other reason cannot adequately be covered in the preceding table. Unless otherwise noted, any concentration of the chemical is satisfactorily handled under the stated conditions.

Chemical	Rubber Temp., °F.	Rubber Hard or Soft	Koroseal Temp., °F.	Koroseal Hard or Soft
Acetic acid	150	H	190	H or S*
Acetic anhydride	150	H	....	......
Ammonium hydroxide	100	H	190	H or S
Ammonium persulphate	100	S	190	H or S
	150	H	....	......
Formaldehyde, to 40%	100	H	190	H or S
Formic acid	100	H	190	H or S*
Furfural	100	H	....	......
Hydrobromic acid	100	S	130	S
	150	H	190	H
Hypochlorous acid	100	S	130	S
Lactic acid	150	H	....	......
Mineral oils	100	H	190	H or S
Nitric acid	....	....	100	S
			190	H
Sulphurous acid	150	H	150	H or S

* Conc. to 10% for Koroseal

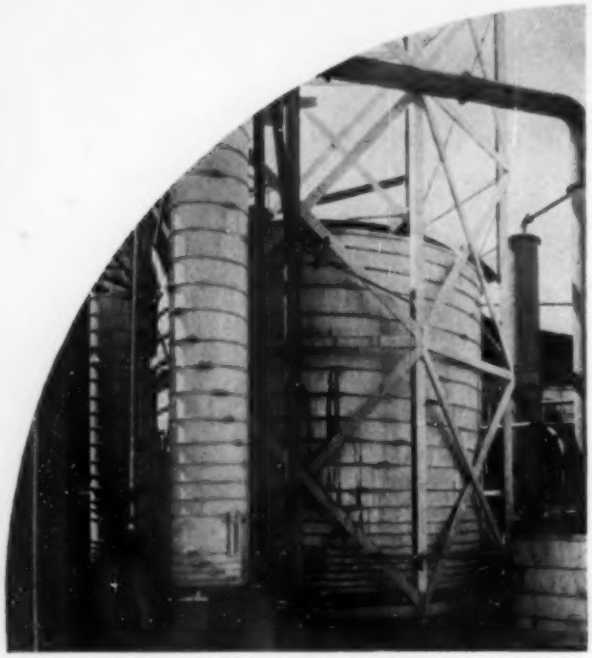
PHYSICAL PROPERTIES OF RUBBER AND RUBBER-LIKE MATERIALS

	Form	Specific Gravity	Compressive Str., Lb. per sq. in.	Tensile Strength, Lb. per sq. in.	Transverse Strength, Lb. per sq. in.	Hardness, Shore Durometer	Max. Temp. for Use, °F.	Effect of Heat	Coef. Lin. Expan., 32-140 °F. x 10^6	Coef. Therm. Conduct. B.t.u. per sq. ft., in., hr., °F.	Abrasion Resistance	Tear Resistance, Lb. per sq. in.	Dielectric Str., Volts per mm.	Effect of Sunlight	Effect of Aging	Machining Qualities
Duprene	....	1.27-3.00	....	200-4,000	......	15-95	300	Stiffens slightly	....	1.45	Equal to rubber	3-30	......	Nil	Stiffens slightly	Can be ground
Koroseal	Hard	1.3-1.4	....	2,000-9,000	......	80-100	212	Softens	....	......	Good	......	30,000-50,000	None	None	Good
Koroseal	Soft	1.2-1.3	....	500-2,500	......	30-80	190	Softens	....	......	Good	......	15,000-30,000	None	None	Can be ground
Plioform	Plastic	1.06	8,500-11,000	4,000-5,000	7,000-9,000	......	160-248	Softens	....	......	......	......	......	Nil	None	
Rubber	Hard	1.12-2	2,000-15,000	1,000-10,000	9,000-15,000	50*-80*	130-160	Softens	35	1.07	......	......	25,000-40,000	Slight discoloration	Nil	Good
Rubber	Soft	0.97-1.25	....	525-600	......	......	150-200	Softens	36	1.07	20 times steel	15-80	25,000-40,000	Cracks	Slight	Can be ground
Rubber	Linings	0.98-1.35	....	......	......	......	190	Softens	....	......	......	......	......	Ages	Tends to harden	

* Scleroscope.

WHO MAKES RUBBER PRODUCTS AND RUBBER-LIKE MATERIALS

MATERIAL	MANUFACTURER (Name and Address)	Composition or Application
Ace	American Hard Rubber Co., New York, N. Y.	Hard and soft rubber linings, shapes, fittings
Ace	American Hard Rubber Co., New York, N. Y.	Rubber paint
Acidseal	B. F. Goodrich Co., Akron, Ohio.	Rubber paint
Armorite	B. F. Goodrich Co., Akron, Ohio.	Abrasion resistant lining
Aurochs	Boston Woven Hose & Rubber Co., Boston, Mass.	Conveyor belts
Bulldog	Boston Woven Hose & Rubber Co., Boston, Mass.	Conveyor belts
Condor	Manhattan Rubber Mfg. Div., Passaic, N. J.	Belts, brake linings, blocks, hose, rolls, pipe
Delhi	Manhattan Rubber Mfg. Div., Passaic, N. J.	Belts, hose
Duprene	E. I. du Pont de Nemours & Co., Wilmington, Del.	Polymerized chloroprene synthetic rubber
Economy	Manhattan Rubber Mfg. Div., Passaic, N. J.	Fire hose
Fire King	B. F. Goodrich Co., Akron, Ohio.	Welding hose
Golden Ply	B. F. Goodrich Co., Akron, Ohio.	Hot-material belting
Goodrich	B. F. Goodrich Co., Akron, Ohio.	Steam hose
Goodyear	Goodyear Tire & Rubber Co., Akron, Ohio	Mechanical rubber goods
Hercules	American Hard Rubber Co., New York, N. Y.	Rubber pails
Hewitt	Hewitt Rubber Corp., Buffalo, N. Y.	Hose, belting, packing
Iron Clad	Boston Woven Hose & Rubber Co., Boston, Mass.	Conveyor belts
Koroseal	B. F. Goodrich Co., Akron, Ohio	Rubber-like plastic
Manhattan	Manhattan Rubber Mfg. Div., Passaic, N. J.	Belts, hose, rolls, lining
Master	Manhattan Rubber Mfg. Div., Passaic, N. J.	Belts
Parock	Manhattan Rubber Mfg. Div., Passaic, N. J.	Oilless bearings
Pilot	U. S. Rubber Co., New York, N. Y.	Rubber-lined pipe
Plioform	Goodyear Tire & Rubber Co., Akron, Ohio	Plastic based on modified rubber
Silver King	Boston Woven Hose & Rubber Co., Boston, Mass.	Conveyor belts
Super-Heat	B. F. Goodrich Co., Akron, Ohio.	Sheet packing
Thiokol	Thiokol Corp., Yardville, N. J.	Olefine polysulphide synthetic rubber
Tornesit	Hercules Powder Co., Wilmington, Del.	Chlorinated rubber for paints
U. S. Permobond Duroline	U. S. Rubber Co., New York, N. Y.	Semi-hard lining
U. S. Permobond Gumline	U. S. Rubber Co., New York, N. Y.	Unvulcanized lining for wood tanks
U. S. Permobond Khemline	U. S. Rubber Co., New York, N. Y.	Soft general-service lining
U. S. Permobond Kleerline	U. S. Rubber Co., New York, N. Y.	Soft non-corrosive lining
U. S. Permobond Tuffline	U. S. Rubber Co., New York, N. Y.	Hard, wear-resisting
Vulcalock	B. F. Goodrich Co., Akron, Ohio.	Rubber linings



Wood

In spite of the enormous number of new metallic materials that have been developed in recent years for the construction of equipment, wood has held its position owing to low cost and satisfactory resistance to many chemicals. It is used mainly in the form of tanks and vats, of rectangular or circular cross section and of widely varying size. The life of wooden equipment depends upon the conditions under which it has to work and upon the care with which it is treated. Dry heat is destructive to timber and a hot humid atmosphere is conducive to decay.

Wood has excellent resistance to a wide variety of neutral and acid salt solutions, both hot and cold, as well as to most organic acids and dilute, nonoxidizing mineral acids. Nitric and strong sulphuric acids and the caustic alkalis, however, are particularly destructive to it.

Physical Properties of Woods and Effects of Chemicals on Woods

	Cypress	Fir	Pine	Redwood	Maple	Oak
Lb. per cu. ft. (12% moisture)	32	30	41	30	44	48
Tensile str., lb. per sq. in.	4,400	3,000	5,100	4,500	—	4,400
Compressive str., lb. per sq. in.	3,560	2,400	3,420	3,400	—	2,800
Thermal cond., B.t.u. per sq. ft., hr., °F., in.	0.83	0.77	0.96	0.76	1.16	1.22
Hardness	Med.	Med.	Hard	Mod. hard	Med.	Hard

Physical Effects of Hot and Cold Chemicals on Woods*

		Cypress		Fir		Pine		Redwood		Maple		Oak	
		Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
HCl	5%	—	—	—	S	—	—	SS,VB	VS,B	—	SS	—	—
	10%	SS	SS	SS	S	—	SS	SS,VB	VS,B	—	S	—	SS
	25%	SS	VS,VB	SS	VS,VB	SS	S	SS,VB	VS,VB,Ch	S,B	VS,VB	SS,SB	VS,VB
	50%	S,Cl,SB		SS,Cl		SS		S,VB		S,B		S,B	
	conc.	VS,B,Cl		VS,B,GR		VS,B,Cl		VS,VB		VS,B,Sh,Cl		VS,B,Di,Ex,Cl	
H_2SO_4	1%	SS	S	SS	S	—	—	SS,B	VS	—	SS	—	W
	5%	SS	S	SS	S	—	SS	VS,B	VS,B	—	S	SS	SS
	10%	SS	VS,P	S	S	SS	SS	VS,B	VS,VB	SS,B	S	SS,SB	SS
	25%	SS,SB	VS,VB	S,B	VS,VB	SS	VS,VB	VS,VB	VS,VB,Ch	VS,VB	VS,VB	SS,B	VS,VB
HNO_3	5%	—	S	SS	VS	—	S,Shd	VS,VB	VS,VB	SS	VS,Shd	SS,GR	S,Cl,Shd
	10%	—	VS,Shd	SS	VS,Shd	SS	S,Shd	VS,VB	VS,VB,Cl,Shd	SS,SB	VS,Shd	S,B,GR,Sh	S,Cl,Shd
	25%	S,B	Shd,VS	VS,B	VS,Shd	SS,B,Cl	S,Shd	VS,VB	VS,VB,Cl,Shd	S,SB,Sh	VS,Shd	VS,VB,GR,Sh,Cl	S,Cl,Shd
NaOH	1%	—	SS	—	Sh,GR	—	—	VS,W,SB,GR	S	Cl	Sh	Sh,VH,Di	VH,Sh,Di
	5%	—	SS	SS	Sh,GR	—	—	VS,SB,GR	S	Sh	Sh	Sh,VH,Di,GR	VH,Sh,Di
	10%	—	SS	SS,GR	Sh,GR	SS	VH,Sh,Di,GR	VS,GR,P	S,Sh,Di,GR	Sh,GR,W		Sh,VH,Di,GR,W,P	VH,Sh,Di,GR
	25%	SS,P	SS	SS,GR,P	GR	SS	VH,GR,W	SS,GR,P	S,Sh,Di,GR,B	Sh,GR,SS,P	W,GR	SS,GR,W,P	WH,GR
$Ca(OCl)_2$	filtered	SS,FZ,GR		SS,FZ,GR		FZ		S,GR,B,Sh,FZ		SS,FZ,Sh		GR,FZ	
	5% susp.	SS,FZ		SS,FZ		FZ		S,GR,B,Sh,FZ		SS,FZ		GR,FZ,SP	

* Taken from a table published by the Hauser-Stander Tank Co., based on tests on small wood samples conducted by S. J. Hauser and Clarence Bahlman. The effects were noted after 8 days in hot solutions, 1 month in cold solutions, and 1 week in cold, concentrated HCl. The symbols used in the table to record the observations have the following significance: SS, slightly soft; S, soft; VS, very soft; VH, very hard; SB, slightly brittle; B, brittle; VB, very brittle; P, pliable; SP, slightly pliable: Sh, slightly shrunken; Ex, noticeably expanded; Cl, cracked lengthwise; W, warped; Di, considerably distorted; GR, grain raised or roughened; FZ, covered with downy "fuzz;" Ch, charred; Shd, shredded, easily picked apart. A dash denotes no effect; a space, no test. Tests on other materials including water, linseed oil, turpentine, cottonseed oil, various concentrations of acetic acid, sodium carbonate, bisulphite, sulphide and chloride, and calcium hydroxide and chloride, showed distinctly minor effects, principally slight softening and roughening, with maple, pine and cypress least affected, and redwood showing the most frequent effects.

Who Makes Wood Tanks and Pipe for Chemical Applications

Acme Tank Co., New York, N. Y.
Atlantic Tank Corp., North Bergen, N. J.
Axtell Co., Fort Worth, Tex.
Baltimore Cooperage Tank & Tower Co., Baltimore, Md.
W. E. Caldwell Co., Louisville, Ky.
A. J. Corcoran, Inc., Jersey City, N. J.
Cypress Tank Co., Shreveport, La.
Dempster Mill Mfg. Co., Beatrice, Neb.
G. Elias & Bro., Buffalo, N. Y.
Federal Pipe & Tank Co., Seattle
Fleming Tank Co., Pittsburgh, Pa.
General Tank Corp., Kearny, N. J.
Amos H. Hall & Sons, Philadelphia
Hauser-Stander Tank Co., Cincinnati, Ohio
R. R. Howell & Co., Minneapolis, Minn.
Johnson & Carlson, Chicago, Ill.
Kalamazoo Tank & Silo Co., Kalamazoo, Mich.
Michigan Pipe Co., Bay City, Mich. (Pipe)
National Tank & Pipe Co., Portland, Ore.
New England Tank & Tower Co. Everett, Mass.
Pacific Cooperage Co., Portland, Ore.
Redwood Mfrs. Co., San Francisco
Wendnagel Co., Chicago, Ill.
A. Wykoff & Son Co., Elmira, N. Y. (Pipe)

INDEX

Heat, Abrasion and Corrosion Resistant Materials

Chemical Engineering NEWS

Petroleum Technologists Hold Conference

THE eighth annual Cracking Development Conference, attended by a group of leading petroleum technologists, held its sessions, Sept. 22-24, at Essex House in New York. Participating in the Conference were representatives of the Standard Oil Co. (Indiana), The Texas Co., The Standard Oil Co. of N. J., Gasoline Products Co., and The M. W. Kellogg Co. William F. Moore, president of Gasoline Products Co., was general chairman of the meetings.

The object of the Cracking Development Conference is to correlate experimental and plant development work in pyrolytic cracking, which is carried on in the laboratories and refineries of the participating companies. Development of new features in the design and operation of equipment for pyrolytic cracking is a function of several associated refiners, the results of which are available to licensees. Designs and improvements pertaining to the several processes, as well as combination units, are licensed to the industry under the scope of cracking patent rights of the Gasoline Products Co.

Precautions Against Dust And Vapor Explosions

WARNING against dust and solvent-vapor explosions was given in an address of Dr. David J. Price, chief of the chemical engineering division of the Bureau of Chemistry and Soils, as he spoke before the American Soybean Association in annual convention at Cedar Rapids on September 15. The warning was particularly constructive because it reduced to specific recommendations the way in which safety can be achieved in such plants. Outstanding recommendations are: 1. Follow the safety code for terminal grain elevators, with good housekeeping as the prime essential to minimizing dust; 2. Observe in milling and processing operations the code provisions for dust control in the flour and feed mill code; 3. Segregate elevating, grinding, and milling processes, if feasible, with adequate roof and wall vents to minimize explosion damage; 4. Observe similar precautions in plants preparing protein products, particularly in drying; 5. Segregate dryers where inflammable dust may be present; 6. Install dust collectors, outside if possible, otherwise with generous venting; 7. For extraction units, observe all customary solvent precautions of recognized codes; 8. If flammable solvents are used, install flammable-vapor detector.

U. S. Industrial Alcohol Co. Thirtieth Anniversary

SUBSTANTIAL expansion in the manufacture of industrial alcohol began just thirty years ago, when Congress passed the Denatured Alcohol Law of 1906 and the U. S. Industrial Alcohol Co. was organized. Because of the heavy tax on ethyl alcohol before 1906, there was little incentive to find new uses for it. When applied chemistry was coming into its period of greatest development, about 1900, alcohol was used "industrially" for the preparation of medicines and perfumes, and, in limited quantities, as a solvent.

At this period certain industries, particularly the hat manufacturers, sponsored legislation which resulted in the passage of the Denatured Alcohol Law of 1906. This bill authorized the sale of alcohol for industrial purposes free of the burdensome tax.

The U. S. Industrial Alcohol Co. was incorporated on October 17, 1906, shortly after the new law was passed, and was ready to deliver alcohol when the law became effective on January 1, 1907.

During the first year under the new law, production for the industry amounted to less than two million gallons. This consisted of Completely Denatured Formula Nos. 1 and 2 and Specially Denatured Alcohol, Formula No. 1.

Most of the industrial alcohol was manufactured at that time from domestic grain. However, a search for cheaper raw material led to the successful utilization of blackstrap molasses. U.S.I. chemists contributed much to the development of methods for using molasses to produce high quality ethyl alcohol.

Lighting and heating were the principal outlets for Completely Denatured Alcohol in 1907, while Specially Denatured Alcohol had already assumed importance as a shellac solvent.

U.S.I. played a large part in developing and furthering uses for alcohol in the years that followed.

Dr. A. McLaren White Dies

ON Sept. 23, Alfred McLaren White, head of the Department of Chemical Engineering at the University of Virginia, died from nephritis in the Presbyterian Hospital in New York. A serious illness last spring rendered acute a latent kidney infection. It was thought that a summer's rest had restored his health. However, he was taken ill again and had to be transferred to the hospital.

Professor White was born in Ann Arbor, Mich, July 1, 1904. After completing a course in chemical engineering at the University of Michigan in 1925, he attended the University of California from which he received an M.S. degree the following year. Two years later he graduated with an Sc.D. degree from the University of Michigan.

On completing his technical education he accepted the assistant professorship in the department of chemical engineering at the Georgia School of Technology. Two years later he transferred to the University of North Carolina where he was made an associate professor. In 1934, he was made head of the Department of Chemical Engineering at that university. Recently Professor White had accepted a similar position at the University of Virginia.

Dr. White was interested in the affairs of the American Institute of Chemical Engineers since the time of his election as an associate member in 1929. In 1934 he transferred to active membership on meeting the age requirement for this classification. In 1933 he was appointed secretary of the Committee on Student Chapters, and held the office of chairman of the committee from 1934 to the time of his demise. These years covered one of the most active periods of the committee's history. He was also counsellor of the student chapter of the Institute at the University of North Carolina during his entire term of service at that institution; and a member of several other A.I.Ch.E. committees.

In addition to his American Institute of Chemical Engineers membership, Dr. White was a member of the American Chemical Society and the Elisha Mitchell Scientific Society.

Pooling of Power Supply In Tennessee

UNDER Presidential encouragement, negotiations have been carried on actively during the past month in an effort to secure a suitable pooling of power supply in and about the Tennessee Valley. Peacemaking between T.V.A. public-ownership advocates and the private-operation leaders of Commonwealth and Southern is not easy. Even first appearances of cooperation are not convincing to Washington observers.

T.V.A. has announced three important contracts for sale of power to industry. These will supply Monsanto Chemical Co., Aluminum Co. of America, and Volunteer Portland Cement Co. with energy for important industrial processing in the Valley. It is definitely known that several other big companies seeking additional power supply in the South are negotiating for contracts. One of the important limitations on progress is the inability of T.V.A. to give any assurances regarding future competition with present contractors seeking to make market developments in that area. In some cases there is not even assurance that T.V.A. would not itself later become an active competitor, should conditions make that administratively expedient.

Careful analysis of the rate schedules offered by T.V.A. indicates that this Government generated power is not particularly cheap. It would, of course, cost much less than formerly prevailing rate schedules could provide. But for many power-using enterprises the cost would certainly be marginal or higher. Strangely enough the differential between continuous and seasonal (9 or 10 months) power is not as great as was commonly anticipated when T.V.A. first began its developments. In most cases the lowest power available under any circumstances is 2.5 mills per kilowatt hour, and most rates will average substantially higher than this.

Chemical Engineers Will Meet in Baltimore

ON Nov. 11-13, the 29th Annual Meeting of the American Institute of Chemical Engineers will be held at the Lord Baltimore Hotel, Baltimore, Md. Sheppard T. Powell is chairman of the local committee in charge with Dr. E. W. Guernsey, vice-chairman, and F. C. Hettinger, secretary-treasurer.

The first session will open at 9.30 on Wednesday morning, Nov. 11. As usual the mornings will be given over to technical sessions with plant visits arranged for the afternoons. The annual business meeting is scheduled for Nov. 12 and 13 when annual reports from the committee chairmen will be presented. The tellers will announce the results of election of officers and directors at a brief business meeting on the opening day of the meeting.

A national student meeting will be held under the auspices of the Committee on Student Chapters in Baltimore on the day before the regular meetings of the Institute.

Chromium Plating Suit Won by General Motors

IN the latter part of September, the United States Court of Appeals, New York, handed down a decision in favor of General Motors Corp. The suit was that of United Chromium, Inc., of New York, against General Motors Corporation, the New Departure Manufacturing Co. of Bristol, Conn., a division of General Motors, and the Bassick Co. of Bridgeport, Conn. It was filed in February, 1933, subsequently decided for the plaintiffs by the United States District Court at New Haven, Conn., and appealed to the Circuit Court of Appeals by the defendants.

The suit involved the validity of the patents for the generally used process of chromium plating. The decision was of further interest in that it credited the invention to Marvin J. Udy of Niagara Falls.

Properties of Plastics Under Investigation

METHODS for determining the properties of plastic materials are to be investigated by the Bureau of Standards. The first stages of this work involve a survey of present practice in testing as recommended by the major producers and users of some of the outstanding materials. A letter is going out to a number of such companies asking them for suggestions regarding which properties are most important with respect to performance testing and what methods of test are recognized or recommended by the company.

This work will not include, at least at any early stage, the drafting of Federal specifications. The problem is rather an effort at correlation of test procedures and a definition of properties in common terms practical for use in the industries concerned. This work will be directed by Warren E. Emley, chief of the division in which is the plastics section of the Bureau. He will be assisted by Dr. Gordon Kline, chief of that section. Suggestions and technical information will be welcome from all sources.

Medal Awards to Dr. Landis And Thomas Midgley, Jr.

AWARD of medals to two outstanding American chemists is announced by the American Section of the Society of Chemical Industry, of which Dr. Foster D. Snell of Brooklyn, N. Y., is honorary secretary.

The Chemical Industry Medal for 1936 goes to Dr. Walter S. Landis, vice-president of the American Cyanamid Company, New York, "for valuable application of research to the chemistry and economics of the fertilizer industries."

Thomas Midgley, Jr., vice-president of the Ethyl Gasoline Corp., New York, and of Kinetic Chemicals, Inc., Detroit, wins the William H. Perkin Medal for 1937 "for distinguished work in applied chemistry, including the development of antiknock motor fuels and safe refrigerants."

"Dr. Landis was a pioneer in the application of chemistry to the production of concentrated fertilizers," declares the announcement. "He has played an important role in that industry for thirty years. He was probably the first to produce argon in large commercial quantities.

"Thomas Midgley's work resulted in the creation of the entire ethyl gasoline industry with all that this implies—use of higher compression engines, greater flexibility of automobile operation, and other advances. Mr. Midgley's more recent discovery of non-toxic refrigerants promises to be equally fundamental in refrigeration and air conditioning."

Bureau of Mines Develops New Potash Process

INTERESTING possibilities of making potassium sulphate are suggested by a discovery of the Reno station of the U. S. Bureau of Mines. It has been noted that by fusing together borax and alunite there results a melt which solidifies in two layers. The lower heavier layer is practically pure potassium sulphate and contains almost 100 per cent of the potash in the original mineral. All the rest of the constituents of the melt form the other, more bulky layer.

No appraisal has yet been made of the possible economic significance of this observation. It is suggested, however, that perhaps this will make possible direct production of potassium sulphate at a price permitting shipment from the Intermountain country where such process would most logically be applied to alunite. The Bureau is continuing further small scale experiments in order to define the limitations of composition under which this separation will work.

NEWS FROM WASHINGTON

Washington News Bureau
McGraw-Hill Publishing Co.
Paul Wooton, Chief

After a year of deliberation, the Federal Trade Commission on September 24 finally announced a tentative approval of rules for regulation of the fertilizer industry. In general these trade practice definitions are very acceptable; but the industry is greatly disappointed that no clean-cut decision was granted with respect to open price filing.

As is customary, the rules promulgated in tentative form were in two groups. The first become virtually legally binding, with violation constituting actionable violation of law. Group 2 is regarded by the Commission merely "as an expression of the industry." In that group it is recognized that the industry may gather and disseminate statistical information, but *not* undertake to influence prices in the direction of restriction of competition.

The pertinent rule does not explicitly authorize the filing of prices for publication through a central authority. Some believe, however, that such open price filing would be legal and permissible, especially in view of the precedent of other industries' activities which have passed F.T.C. scrutiny. In the formal hearing on October 9 the representatives of the industry sought a more definite recognition of this practice. It is doubtful, however, whether the Commission will ever go so far as the industry feels would be desirable in order to restrain some of the more ruthless price cutters.

Tariff and Trade Changes

For political reasons, if no other, additional negotiations of bilateral trade agreements were not to be expected during the second half of 1936. The two pending negotiations of interest to chemical industry were with Spain and Italy. Obviously neither of those nations is in position to carry on negotiations, much less to enter new trade commitments of interest to the United States Government.

It has been announced, however, that trade agreement negotiations would be resumed within a short time. The State Department officials even ventured the suggestion that twelve more treaties of this sort would probably be arranged within the next year. This will, assuming continuance of the New Deal, result in further tariff cuts.

The "unfavorable" balance of trade noted in recent months was not unexpected. Government officials have been preparing the minds of observers for this expected phenomenon. It is obviously impossible for an excess of goods exports over imports to be maintained at a time when every other fiscal consideration influences the trade balance in the reverse direction.

Chemical industries are probably more importantly concerned with respect to changes in Japanese trade than with any other. The continued influx of process industry goods produced with very cheap labor is occasioning study by executives of the possibility of invoking a flexible tariff law for raising rates. No such increases have yet been advanced far enough in the Tariff Commission procedure to deserve general consideration by the industry.

Alcohol

Washington has been watching the alcohol industry, operating as usual as a prolific news source. Officials argue that the new CD formulas authorized this summer will stand the test of bootlegger cleaning very well. It is believed that the extra cost of the new formulas over the old will be negligible. At most the difference in cost is said to be from 0.5 to 1.0 cents per gallon for denaturant. Rise in the cost of the customary raw materials as a result of drought shortages will be much more important than this in the effect on costs.

Advocates of methanol-denatured alcohol regard the announcement of new formulas of other types as a delay but not a final rejection of their ideas. The methanol producers are, however, much more interested in the growing market for that solvent as a widely used commodity than in the prospect of restoration of methanol as a denaturant.

New administrative regulations of the Treasury Department have been issued in great number, both with respect to industrial alcohol and beverages containing alcohol. These are perhaps a small factor in encouraging the trend which is noted by Washington toward substitution of other solvents which are not regulated by so much administrative detail. Widespread use of methanol in industry is cited as the most notable trend.

Anti-freeze controversy of the perennial type shows itself in Washington by pleas for aid desired by the various groups of producers. All evidence officially available seems to indicate that methanol is continuing to make substantial inroads into the anti-freeze business of alcohol. Government agencies watch this trend with interest, but zealously avoid any partisan gestures.

The recent report of U. S. Consul S. B. Redecker, of Frankfort-on-Main, Germany, that "fuel alcohol of agricultural origin will steadily diminish in importance as motor fuel in Germany" has stirred much discussion, even controversy. The charge that this alcohol has never been popular in that country and that its compulsory consumption will be abolished altogether, are immediately denied by Farm Chemurgic Council spokesmen. In this they quote Dr. Friedrich Bergius, the noted German chemist visitor who consented to an interview undertaking to refute the pessimistic report from his homeland. Dr. Bergius explains that the decline in consumption recently noted is because of the shortage of potatoes from which to make the alcohol.

There is interesting parallel between the German difficulties and those of America. The Chemurgic experimenters in Kansas have had to go as far afield as Alabama sweet potatoe surpluses in order to get adequate supplies of raw material.

Stream Pollution

New legislation on stream pollution will be vigorously pressed by Senator Lonergan of Connecticut in the next Congress. The two bills which passed the House and the Senate last session were not reconciled in conferences, due to differences in fundamental philosophy regarding control of industrial wastes. There will be time in the next session to reconcile the two groups of proponents, and enactment of significant measures is expected.

Leaders of industrial groups investigating these matters are urging that Public Health Service be the agency designated. Investigations are now in progress by several trade association leaders in the hope of bringing to bear enough influence on those drafting new legislation so that constructive technical handling of any new legislation will be sure. The fear is that if some new overzealous body is established, without the background of experience in public administration which the Public Health Service has, there may result needlessly burdensome regulations without the benefit of improved quality in water supplies. Manufacturing Chemists' Association is aggressively participating in the investigations.

The MARKETS

SHIPPING directions for raw materials have been coming to hand in good volume in the last month and the movement of chemicals for the final quarter of this year promises to live up to the optimistic predictions recently heard.

Chemical carloadings in the fourth quarter of 1936 are expected to be about 6.6 per cent above actual loadings in the same quarter in 1935, according to estimates compiled by the 13 Shippers' Regional Advisory Boards.

Sales of goods both by manufacturers and wholesalers showed substantial gains in August compared with the same month last year, and small but favorable gains over July of this year, according to a survey made jointly by the Bureau of Foreign and Domestic Commerce and the National Association of Credit Men and released for publication on Sept. 30.

Total net sales of 528 manufacturers throughout the country registered an increase of more than 18 per cent in August 1936 over August 1935. All the 15 industries shown in the survey had increases ranging from 9 per cent for leather and its products to over 42 per cent for iron and steel and their products. Stone, clay, and glass products, motor-vehicle parts, and non-ferrous metals also were high, each exceeding 35 per cent. Without adjustment for seasonal influences, August sales registered an increase of 1 per cent from July of this year.

Under the grouping of chemicals and allied products a total of 42 firms reported sales which showed a drop of 2.1 per cent for August as compared with those for August last year. Reports for the paint and varnish industry were more encouraging with August sales running 24.5 per cent above those for August 1935.

The price movement in the last month has been upward. Higher quotations are in effect for nitrate of soda, denatured alcohol, zinc oxide, glycerine, and some of the dry colors. Phosphate of soda which has been under severe price competition also is reported to be firmer with attempts on the part of some large consumers of tri-sodium phosphate to renew contracts at the same prices as paid for 1936 deliveries said to have been turned down by producers.

Some of the vegetable oils on the other hand have shown an easier price trend but this was more than offset by higher values for animal fats.

Denied relief by the State Department and faced with a constantly increasing total of imports of babassu oil under the Brazilian reciprocal trade agreement American food industries and dairy interests are planning to appeal to the coming session of Congress for imposition of a tax of three cents per pound on oleo containing the South American product.

Under the terms of the trade agreement with Brazil the oil can not be taxed, but this treaty agreement does not apply to the products containing the oil, and according to estimates made in Washington, almost 25 percent of babassu oil is being used in the manufacture of oleo for American consumption. This it is being asserted, makes the oil a direct and dangerous rival of American products.

Though the State Department has placed a heavy foot on the protest filed with it by such organizations as the National Dairy Union, the National Grange, the Cotton Seed Producers, the National Cooperative Nut Producers Federation, those agencies are still hopeful.

Proposals for bids on various government requirements are beginning to be issued with the stipulations outlined in the regulations recently promulgated for the administration of the Walsh-Healey Act. Since some time must elapse before prevailing wages can be established reference in present stipulations is to hours only. As overtime is allowed this raises no important issue where the entire plant operates on a forty-hour schedule. Difficulties arise however when plants have a different schedule.

An informal opinion has been expressed that part-time employment of the same employees on government contracts and on other work on a different scale would not be allowed. No objection was seen, however, to the bringing in of different employees to work exclusively on government orders on a part-time basis.

The regulations provide for the use of materials manufactured before the act became effective. This presents complications because portions of materials used may not comply. This is expected to make stock taking a subject of controversy between management and labor. Some prospective bidders feel that the elimination of the subcontractor from the bill relieves them of the necessity of following materials back to their source.

Two groups of manufacturers are known to have asked the Secretary of Labor for a ninety-day stay of the act until they can take care of the far-reaching adjustments they must make. The Navy Department claims the law does not apply to purchase of fuel oil.

Among recent developments in the chemical industry abroad are: The German dye industry has been operating at a rapidly increasing rate during the past two years and while official statistics are not available the current output is unquestionably far above that of depression years and may be equal if not in advance of the pre-depression period.

Chile produced 1,220,000 metric tons of nitrates during the year ended June 30, 1936, compared with 1,133,000 during the preceding fiscal period, according to reports from Santiago. Exports during these periods increased from 1,280,000 to 1,360,000 metric tons.

CHEM. & MET.
Weighted Index of
CHEMICAL PRICES

Base = 100 for 1927

This month	86.76
Last month	86.34
October, 1935	87.01
October, 1934	87.71

Zinc oxide was higher in price effective Oct. 1. Forward positions for nitrate of soda and sulphate of ammonia also were higher. Spirits of turpentine held a low average price but denatured alcohol was marked up and better conditions appear in prospect for solvents.

CHEM. & MET.
Weighted Index of Prices for
OILS AND FATS

Base = 100 for 1927

This month	92.56
Last month	91.30
October, 1935	94.08
October, 1934	74.02

Many of the vegetable oils sold below the levels of a month ago, but animal fats were firmer and had the effect of influencing the index number to advance.

Current PRICES

The following prices refer to round lots in the New York market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to October 10.

Industrial Chemicals

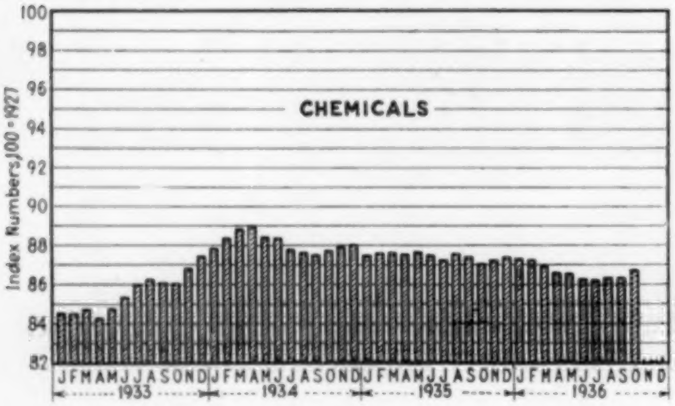
	Current Price	Last Month	Last Year
Acetone, drums, lb	$0 08 -$0.09	$0 08 -$0 09	$0 12-$0 12½
Acid, acetic, 28%, bbl., cwt	2.45 - 2.70	2 45 - 2 70	2.45 - 2.70
Glacial 99%, drums	8.43 - 8.68	8 43 - 8.68	8.43 - 8.68
U. S. P. reagent	10.52 -10.77	10.52 -10.77	10.52 -10.77
Boric, bbl., ton	105.00-115.00	105.00-115.00	105.00-115.00
Citric, kegs, lb	.25 - .28	.26 - .29	.28 - .31
Formic, bbl., ton	.11 - .11½	.11 - .11½	.11 - .11½
Gallic, tech., bbl., lb	.60 - .65	.60 - .65	.60 - .65
Hydrofluoric 30% carb., lb	.07 - .07½	.07 - .07½	.07 - .07½
Lactic, 44%, tech. light, bbl., lb	.11½- .12	.11½- .12	.12 - .12½
Muriatic, 18°, tanks, cwt	1.00 - 1.10	1.00 - 1.10	1.00 - 1.10
Nitric, 36°, carboys, lb	.05 - .05½	.05 - .05½	.05 - .05½
Oleum, tanks, wks., ton	18.50 -20.00	18.50 -......	18 50 -20.00
Oxalic, crystals, bbl., lb	.11½- .12½	.11½- .12½	.11½- .12½
Phosphoric, tech., c'bys., lb	.09 - .10	.09 - .10	.09 - .10
Sulphuric, 60°, tanks, ton	11.00 -11.50	11.00 -11.50	11 00 -11.50
Sulphuric, 66°, tanks, ton	15.50 -......	15.50 -......	15.50 -......
Tannic, tech., bbl., lb	.20 - .30	.20 - .30	.23 - .35
Tartaric, powd., bbl., lb	.24 - .25	.24 - .25	.24 - .25
Tungstic, bbl., lb	1.50 - 1.60	1.50 - 1.60	1.50 - 1.60
Alcohol, Amyl			
From Pentane, tanks, lb	14.3 -......	14.3 -......	.15 -......
Alcohol, Butyl, tanks, lb	.08½-......	.08½-......	.13 -......
Alcohol, Ethyl, 190 p'f., bbl., gal	4.14 -......	4.27½-......	4.27½-......
Denatured, 190 proof			
No. 1 special, dr., gal wks	.32 -......	29 -......	.28 -......
Alum, ammonia, lump, bbl., lb	.03 - .04	.03 - .04	.03 - .04
Chrome, bbl., lb	.04½- .05	.04½- .05	.04½- .05
Potash, lump, bbl., lb	.03 - .04	.03 - .04	.03 - .04
Aluminum sulphate, com, bags cwt	1.35 - 1.50	1.35 - 1.50	1.35 - 1 50
Iron free, bg., cwt	2.00 - 2.25	2.00 - 2.25	1.90 - 2.00
Aqua ammonia, 26°, drums, lb	.02½- .03	.02½- .03	.02½- .03
tanks, lb	.02½- .02¾	.02½- .02¾	.02½- .02¾
Ammonia, anhydrous, cyl., lb	.15½- .16	.15½- .16	.15½- .16
tanks, lb	.04½-......	.04½-......	.04½-......
Ammonium carbonate, powd. tech., casks, lb	.08 - .12	.08 - .12	.08 - .12
Sulphate, wks., cwt	1.25 -......	1.25 -......	1.20 -......
Amylacetate tech., tanks, lb	.12 - .135	.12 - .135	.142-......
Antimony Oxide, bbl., lb	.12½- .13½	.12½- .13½	.12½- .12¾
Arsenic, white, powd., bbl., lb	.03½- .04	.03½- .04	.03½- .04
Red, powd., kegs, lb	.15½- .16	.15½- .16	.15½- .16
Barium carbonate, bbl., ton	56.50 -58 00	56.50 -58.00	56 50 -58 00
Chloride, bbl., ton	72.00 -74.00	72 00 -74.00	72.00 -74.00
Nitrate, cask, lb	.08½- .09	.08½- .09	.08½- .09
Blanc fixe, dry, bbl., lb	.03½- .04	.03½- .04	.03½- .04
Bleaching powder, f.o.b., wks., drums, cwt	2.00 - 2.10	2.00 - 2.10	1.90 - 2.00
Borax, gran., bags, ton	44.00 -49.00	44.00 -49.00	44.00 -49 00
Bromine, cs., lb	.36 - .38	.36 - .38	.36 - .38
Calcium acetate, bags	2 10 -......	2.10 -......	2.10 -......
Arsenate, dr., lb	.06 - .07	.06 - .07	.06 - .07
Carbide drums, lb	.05 - .06	.05 - .06	.05 - .06
Chloride, fused, dr., del., ton	20 00 -33.00	20 00 -33 00	20.00 -33 00
flake, dr., del., ton	22 00 -35.00	22.00 -35.00	22.00 -35.00
Phosphate, bbl., lb	.07½- .08	.07½- .08	.07½- .08
Carbon bisulphide, drums, lb	.05½- .06	.05½- .06	.05½- .06
Tetrachloride drums, lb	.05½- .08½	.05½- .06	.05½- .06
Chlorine, liquid, tanks, wks., lb	2.15 -......	2.15 -......	2 00 -......
Cylinders	.05½- .06	.05½- .06	.05½- .06
Cobalt oxide, cans, lb	1.41 - 1.51	1.41 - 1.51	1 39 - 1.45
Copperas, bgs., f.o.b., wks., ton	15.00 -16.00	15.00 -16.00	14.00 -15.00

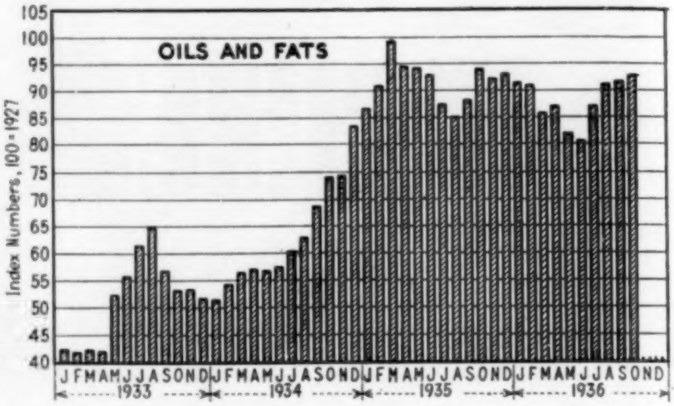
	Current Price	Last Month	Last Year
Copper carbonate, bbl., lb	.08½- .16	.08 - .16	.08½- .16
Sulphate, bbl., cwt	4.00 - 4.25	4.00 - 4.25	3.85 - 4.00
Cream of tartar, bbl., lb	.16½- .17	.16½- .17	.16½- .17
Diethylene glycol, dr., lb	.16½- .20½	.16½- .20½	.16½- .20½
Epsom salt, dom., tech., bbl., cwt	1.80 - 2.00	1.80 - 2.00	2.10 - 2.15
Ethyl acetate, drums, lb	.07 -......	.07 -......	.08½-......
Formaldehyde, 40%, bbl., lb	.06 - .07	.06 - .07	.06 - .07
Furfural, dr., lb	.10 - .17½	.10 - .17½	.10 - .17½
Fusel oil, ref. drums, lb	.16 - .18	.16 - .18	.16 - .18
Glaubers salt, bags, cwt	.85 - 1.00	.85 - 1.00	1.00 - 1.10
Glycerine, c.p., drums, extra, lb	.19½-......	.19½-......	.14 - .14½
Lead:			
White, basic carbonate, dry casks, lb	.06½-......	.06½-......	.06½-......
White, basic sulphate, sck., lb	.06 -......	.06 -......	.06 -......
Red, dry, sck, lb	.07 -......	.07 -......	.06¾-......
Lead acetate, white crys., bbl., lb	.10½- .11	.10½- .11	.10½- .11
Lead arsenate, powd., bbl., lb	.09 - .10	.09 - .10	.09 - .10
Lime, chem., bulk, ton	8.50 -......	8.50 -......	8.50 -......
Litharge, pwd., csk., lb	.06 -......	.06 -......	.05¾-......
Lithophone, bags, lb	.04½- .05	.04½- .05	.04½- .05
Magnesium carb., tech., bags, lb	.06 - .06½	.06 - .06½	.06 - .06½
Methanol, 95%, tanks, gal	.33 -......	.33 -......	.33 -......
97%, tanks, gal	.34 -......	.34 -......	.34 -......
Synthetic, tanks, gal	.35½-......	.35½-......	.35½-......
Nickel salt, double, bbl., lb	.13 - .13½	.13 - .13½	.12½- .13
Orange mineral, csk., lb	.10 -......	.10 -......	.09¾-......
Phosphorus, red, cases, lb	.44 - .45	.44 - .45	.44 - .45
Yellow, cases, lb	.28 - .32	.28 - .32	.28 - .32
Potassium bichromate, casks, lb	.08½- .09	.08½- .09	.07¾- .08½
Carbonate, 80-85%, calc. csk., lb	.07 - .07½	.07 - .07½	.07 - .07½
Chlorate, powd., lb	.08 - .08¾	.08 - .08¾	.08¾- .09
Hydroxide (c'stic potash) dr., lb	.06¼- .06½	.06¼- .06½	.06¼- .06½
Muriate, 80% bgs., ton	23.00 -......	23.00 -......	22.00 -......
Nitrate, bbl., lb	.05½- .06	.05½- .06	.05½- .06
Permanganate, drums, lb	.18½- .19	.18½- .19	.18½- .19
Prussiate, yellow, casks, lb	.18 - .19	.18 - .19	.18 - .19
Sal ammoniac, white, casks, lb	.04½- .05	.04½- .05	.04½- .05
Salsoda, bbl., cwt	1.00 - 1.05	1.00 - 1.05	1.00 - 1.05
Salt cake, bulk, ton	13.00 -15.00	13.00 -15.00	13.00 -15.00
Soda ash, light, 58%, bags, contract, cwt	1.23 -......	1.23 -......	1.23 -......
Dense, bags, cwt	1.25 -......	1.25 -......	1.25 -......
Soda, caustic, 76%, solid, drums, contract, cwt	2.60 - 3.00	2.60 - 3.00	2.60 - 3.00
Acetate, works, bbl., lb	.04¾- .05	.04¾- .05	.04¾- .05
Bicarbonate, bbl., cwt	1.85 - 2.00	1.85 - 2.00	1.85 - 2.00
Bichromate, casks, lb	.06½- .07	.06½- .07	.05¾- .06½
Bisulphate, bulk, ton	15.00 -16.00	15.00 -16.00	15.00 -16.00
Bisulphite, bbl., lb	.03½- .04	.03½- .04	.03 - .04
Chlorate, kegs, lb	.06¼- .06½	.06¼- .06½	.06¼- .06½
Chloride, tech., ton	12.00 -14.75	12.00 -14.75	12.00 -14.75
Cyanide, cases, dom., lb	.15½- .16	.15½- .16	.15½- .16
Fluoride, bbl., lb	.07½- .08	.07½- .08	.07½- .08
Hyposulphite, bbl., cwt	2.40 - 2.50	2.40 - 2.50	2.40 - 2.50
Metasilicate, bbl., cwt	2.75 - 3.00	2.90 - 3.00	3.25 - 3.40
Nitrate, bags, cwt	1.375-......	1.29 -......	1.275-......
Nitrite, casks, lb	.07½- .08	.07½- .08	.07½- .08
Phosphate, dibasic, bbl., lb	.022- .023	.022- .023	.022- .024
Prussiate, yel. drums, lb	.11½- .12	11½- .12	.11½- .12
Silicate (40° dr.) wks., cwt	.80 - .85	80 - .85	.80 - .85
Sulphide, fused, 60-62%, dr., lb	.02¾- 03½	02¾- .03	.02¾- .03
Sulphite, cyrs., bbl., lb	.02¼- .02½	02¼- .02½	.02¼- .02½
Sulphur, crude at mine, bulk, ton	18.00 -......	18 00 -......	18.00 -......
Chloride, dr., lb	.03½- .04	.03½- .04	.03½- .04
Dioxide, cyl., lb	.06½- .08	.06½- .08	.07 - .07½
Flour, bag, cwt	1.60 - 3 00	1.60 - 3.00	1.60 - 3.00
Tin Oxide, bbl., lb	.49 -......	.47 -......	.53 -......
Crystals, bbl., lb	.35 -......	.34 -......	.38 -......
Zinc, chloride, gran., bbl., lb	05 - .06	05 - .06	.05 - .06
Carbonate, bbl., lb	.09 - .11	.09 - .11	.09 - .11
Cyanide, dr., lb	36 - .38	36 - .38	.36 - .38
Dust, bbl., lb	.068- .07	.068- .07	.066- .07
Zinc oxide, lead free, bag., lb	.05¾-......	.05 -......	.05 -......
5% lead sulphate, bags, lb	.05¾-......	.04⅞-......	.04⅞-......
Sulphate, bbl., cwt	2.65 - 3.00	2.65 - 3.00	2.75 - 3.00

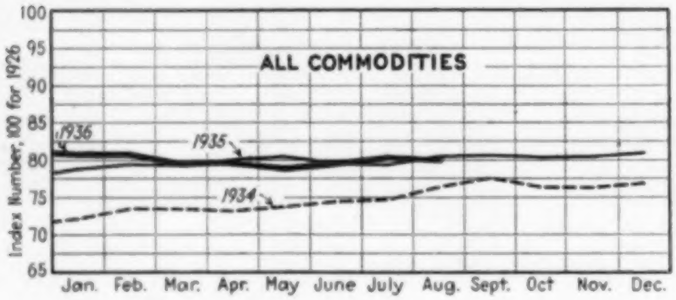
Oils and Fats

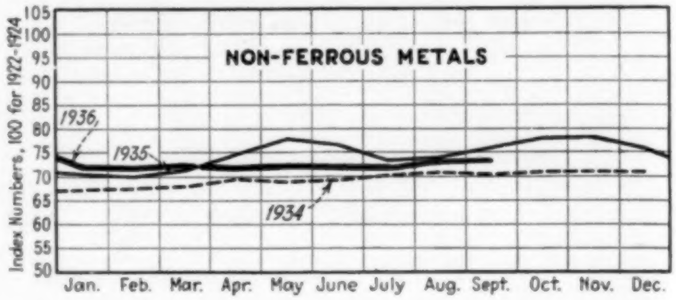
	Current Price	Last Month	Last Year
Castor oil, No. 3, bbl., lb	$0.10 -$0.11	$0.10 -$0.11	$0.09½-$0.10
Chinawood oil, bbl., lb	.14¼-......	.14¼-......	.35 -......
Coconut oil, Ceylon, tanks, N. Y. lb	.05¾-......	.06 -......	.05 -......
Corn oil crude, tanks, (f.o.b. mill), lb	.09¾-......	.09¾-......	.09¾-......
Cottonseed oil, crude (f.o.b. mill), tanks, lb	.08¾-......	.09½-......	.09½-......
Linseed oil, raw car lots, bbl., lb	.097-......	.101-......	.097-......
Palm, casks, lb	.05 -......	.05 -......	.05 -......
Palm kernel, bbl., lb	.05½-......	.05½-......	.05½-......
Peanut oil, crude, tanks (mill), lb	.08¾-......	.09½-......	.09½-......
Rapeseed oil, refined, bbl., gal	.70 -......	.65 -......	.50 -......
Soya bean, tank, lb	.08 -......	.08¼-......	.08½-......
Sulphur (olive foots), bbl., lb	.09¼-......	.09¼-......	.08 -......
Cod, Newfoundland, bbl., gal	.43 -......	.43 -......	.35 -......
Menhaden, light pressed, bbl., lb	.068-......	.068-......	.065-......
Crude, tanks (f.o.b.factory), gal	.30 -......	.30 -......	.28 -......
Grease, yellow, loose, lb	.06½-......	.06¾-......	.06½-......
Oleo stearine, lb	.10 -......	.10¼-......	.11¾-......
Red oil, distilled, d.p. bbl., lb	.09½-......	.09½-......	.09½-......
Tallow, extra, loose, lb	.06¾-......	.06¾-......	.07¾-......

CHEM. & MET.'S WEIGHTED PRICE INDEXES









Coal-Tar Products

	Current Price	Last Month	Last Year
Alpha-napthol, crude, bbl., lb	$0.60 –$0.65	$0.60 –$0.65	$0.60 –$0.62
Refined, bbl., lb	.80 – .85	.80 – .85	.80 – .85
Alpha-napthylamine, bbl., lb	.32 – .34	.32 – .34	.32 – .34
Aniline oil, drums, extra, lb	.14½– .15	.14½– .15	.14½– .15
Aniline salts, bbl., lb	.24 – .25	.24 – .25	.24 – .52
Benzaldehyde, U.S.P., dr., lb	1.10 – 1.25	1.10 – 1.25	1.10 – 1.25
Benzidine base, bbl., lb	.65 – .67	.65 – .67	.65 – .67
Benzoic acid, U.S.P., kgs., lb	.48 – .52	.48 – .52	.48 – .52
Benzyl chloride, tech., dr., lb	.30 – .35	.30 – .35	.30 – .35
Benzol, 90%, tanks, works, gal	.16 – .18	.18 – .20	.15 – .16
Beta-napthol, tech., drums, lb	.24 – .27	.24 – .27	.22 – .24
Cresol, U.S.P., dr., lb	.10 – .11	.10 – .11	.11 – .11½
Cresylic acid, 99%, dr., wks., gal	.73 – .75	.73 – .75	.45 – .46
Diethylaniline, dr., lb	.55 – .58	.55 – .58	.55 – .58
Dinitrophenol, bbl., lb	.29 – .30	.29 – .30	.29 – .30
Dinitrotoluen, bbl., lb	.16 – .17	.16 – .17	.16 – .17
Dip oil, 25%, dr., gal	.23 – .25	.23 – .25	.23 – .25
Diphenylamine, bbl., lb	.38 – .40	.38 – .40	.38 – .40
H-acid, bbl., lb	.65 – .70	.65 – .70	.65 – .70
Napthalene, flake, bbl., lb	.07½– .07½	.07 – .07½	.05½– .06
Nitrobenzene, dr., lb	.08½– .09	.08½– .09	.08½– .10
Para-nitraniline, bbl., lb	.51 – .55	.51 – .55	.51 – .55
Phenol, U.S.P., drums, lb	.14½– .15	.14½– .15	.14½– .15
Picric acid, bbl., lb	.30 – .40	.30 – .40	.30 – .40
Pyridine, dr., gal	1.10 – 1.15	1.10 – 1.15	1.10 – 1.15
Resorcinal, tech., kegs, lb	.65 – .70	.65 – .70	.65 – .70
Salicylic acid, tech., bbl., lb	.40 – .42	.40 – .42	.40 – .42
Solvent naptha, w.w., tanks, gal	.26 –......	.26 –......	.26 –......
Tolidine, bbl., lb	.88 – .90	.88 – .90	.88 – .90
Toluene, tanks, works, gal	.30 –......	.30 –......	.30 –......
Xylene, com., tanks, gal	.30 –......	.30 –......	.30 –......

Miscellaneous

	Current Price	Last Mont	Last Year
Barytes, grid., white, bbl., ton	$22.00–$25.00	$22.00–$25.00	$22.00–$25.00
Casein, tech., bbl., lb	.17 – .18	.17½ – .18	.12 – .13
China clay, dom., f.o.b. mine, ton	8.00 –20.00	8.00 –20.00	8.00 –20.00
Dry colors:			
Carbon gas, black (wks.), lb	.04 – .20	.04 – .20	.04 – .20
Prussian blue, bbl., lb	.37 – .38	.37 – .38	.36½– .37
Ultramarine blue, bbl., lb	.10 – .26	.10 – .26	.06.– .32
Chrome green, bbl., lb	.26 – .27	.26 – .27	.26 – .27
Carmine red, tins, lb	4.00 – 4.40	4.00 – 4.40	4.00 – 4.40
Para toner, lb	.80 – .85	.80 – .85	.80 – .85
Vermilion, English, bbl., lb	1.75 – 1.78	1.59 – 1.60	1.52 – 1.56
Chrome yellow, C. P., bbl., lb	.13 – .14	.12 – .14	.15 – .15½
Feldspar, No. 1 (f.o.b. N.C.), ton	6.50 – 7.50	6.50 – 7.50	6.50 – 7.50
Graphite, Ceylon, lump, bbl., lb	.07 – .08½	.07 – .08½	.07 – .08½
Gum copal Congo, bags, lb	.09 – .10	.09 – .10	.09 – .10
Manila, bags, lb	.09 – .10	.09 – .10	.16 – .17
Damar, Batavia, cases, lb	.13½– .16	.15½– .16	.15½– .16
Kauri No. 1 cases, lb	.19 – .25	.20 – .25	.20 – .25
Kieselguhr (f.o.b. N. Y.), ton	50.00 –55.00	50.00 –55.00	50.00 –55.00
Magnesite, calc, ton	50.00 –......	50.00 –......	50.00 –......
Pumice stone, lump, bbl., lb	.05 – .07	.05 – .08	.05 – .07
Imported, casks, lb	.03 – .40	.03 – .40	.03 – .35
Rosin, H., bbl	7.25 –......	7.25 –......	5.90 –......
Turpentine, gal	.41 –......	.42½–......	.52½–......
Shellac, orange, fine, bags, lb	.25 –......	.25 –......	.25 –......
Bleached, bonedry, bags, lb	.18 –......	.18 –......	.21 –......
T. N. bags, lb	.14½–......	.14½–......	.14 –......
Soapstone (f.o.b. Vt.), bags, ton	10.00 –12.00	10.00 –12.00	10.00 –12.00
Talc, 200 mesh (f.o.b. Vt.), ton	8.00 – 8.50	8.00 – 8.50	8.00 – 8.50
300 mesh (f.o.b. Ga.), ton	7.50 –10.00	7.50 –10.00	7.50 –11.00
225 mesh (f.o.b. N. Y.), ton	13.75 –......	13.75 –......	13.75 –......

INDUSTRIAL NOTES

LINCOLN ELECTRIC RAILWAY SALES CO., Cleveland, has announced the election of J. E. Buckingham as vice-president in charge of sales for the western district with headquarters at 310 South Michigan Blvd., Chicago.

ELECTRO BLEACHING GAS CO. and its associated company, Niagara Alkali Co., Niagara Falls, N. Y., have moved New York offices to 60 East 42d St.

LEEDS & NORTHRUP CO., Philadelphia, has opened an office at 80 Federal St., Boston, Mass. The office is staffed for consulting and sales engineering service.

AMERICAN POTASH & CHEMICAL CORP., Trona, Calif., has appointed Albert A. Hoffman manager of the plant to succeed W. E. Burke who has resigned because of ill health.

AMERICAN MACHINE AND METALS, INC., New York, has opened offices in the Washington Bldg., 15th St. and New York Ave., Washington, D. C. Joseph S. Jones, one of the vice-presidents of the company, is in charge.

RAYON MACHINERY CORP., Cleveland, subsidiary of Industrial Rayon Corp., has appointed George Torrence vice-president and general manager. Mr. Torrence formerly was president of the Link-Belt Co.

GENERAL TIRE & RUBBER CO., Akron, Ohio, plans to open a plant at Wabash, Ind., for the manufacture of mechanical rubber goods.

ARMSTRONG CORK CO., Lancaster, Pa., has purchased the plant at Beaver Falls formerly operated by the Beaver Falls Art Tile Co.

LUKENS STEEL CO., Coatesville, Pa., has promoted Lester M. Curtiss to the position of assistant general superintendent.

WORTHINGTON PUMP AND MACHINERY CO., Harrison, N. J., will hold special meeting on Nov. 9 to vote on plan for the formation of a new company to take over the business and assets of the present corporation.

New CONSTRUCTION

Where Plants Are Being Built in Process Industries

	Current Projects		Cumulative 1936	
	Proposed Work	Contracts	Proposed Work	Contracts
New England..........	$77,000	$47,000	$540,000	$1,067,000
Middle Atlantic........	2,952,000	74,000	12,598,000	10,317,000
South..................	2,150,000	3,034,000	13,858,000	17,587,000
Middle West...........	2,370,000	1,202,000	9,914,000	8,429,000
West of Mississippi.....	315,000	172,000	6,623,000	10,103,000
Far West..............	110,000	38,000	4,190,000	5,914,000
Canada................	165,000	140,000	14,325,000	8,754,000
Total...............	$8,139,000	$4,707,000	$62,048,000	$62,171,000

PROPOSED WORK BIDS ASKED

Carbon Factory—Ohio Carbon Co., A. K. Moulton, pres., 12508 Berea Rd., Cleveland, O., has had plans prepared by George S. Rider Co., archt., Marshall Bldg., Cleveland, for four 1 and 2 story factory buildings. Estimated cost $40,000.

Coke Ovens—Tennessee Coal Iron & Railroad Co., Brown Marx Bldg., Birmingham, Ala., plans to rebuild 73 coke ovens at its Fairfield Works near Birmingham. Estimated cost $2,000,000.

Cotton Seed Oil Mill—Southern Texas Cotton Oil Co., c/o Oscar Robinson, mgr., Harlingen, Tex., will construct a cotton seed oil mill to produce cotton seed oil, cake and various by-products. The owners plan to purchase four hydraulic and six cold presses. Estimated cost $175,000.

Distillery—J. E. Wathen Distilling Co., Uniontown, Ky., will soon award the contract for the construction of a distillery. Estimated cost $150,000.

Drug Factory—The Sun Ray Drug Co., Broad and Wallace Sts., Philadelphia, Pa., plans improvements to its plant and storage buildings. Estimated cost will exceed $40,000.

Factory—Goodyear Tire & Rubber Co., 1144 East Market St., Akron, O., has acquired the factory formerly occupied by the Acme Co. at Windsor, Vt., and plans to alter same for its own use. Estimated cost including equipment will exceed $40,000.

Factory—Republic Bronze Powder Co., c/o A. H. Gross, pres., 3000 Woodhill Rd., Cleveland, O., is having plans prepared by E. G. Hoefler, archt. & engr., 5005 Euclid Ave., Cleveland, for a group of buildings including factory, office, warehouse, etc., on Forbes Rd., Bedford, O. Estimated cost $75,000.

Factory—United States Rubber Co., 184 Commercial St., Malden, Mass., contemplates the construction of a factory on Eastern Ave., Chelsea, Mass.

Fertilizer Factory—F. H. Heidner, 301 Metropolitan Bldg., Toronto, Ont., Can., plans to construct a fertilizer factory for the manufacture of chemical fertilizers. J. I. English, 309 Adelaide St., W., Toronto, archt. Estimated cost may exceed $50,000.

Glass Factory—Pittsburgh Plate Glass Co., Grant Bldg., Pittsburgh, Pa., plans to remodel and reequip its factory at Kokomo, Ind., which has been closed since 1930, for the manufacture of metal and glass store fronts. Estimated cost including equipment may exceed $50,000.

Ink Factory—Braden Sutphin Ink Co., 1736 East 22d St., Cleveland, O., has had plans prepared by Warner & Mitchell, archts., Bulkley Bldg., Cleveland, for the construction of a 2 story, 114 x 165 ft. factory and office building. Estimated cost $125,000.

Laboratory—American Rolling Mill Co., Middletown, O., plans to construct a laboratory. Austin Co., 16112 Euclid Ave., Cleveland, archt. and engr. Estimated cost $40,000.

Laboratory—Lanova Corp., 369 Lexington Ave., New York, N. Y., plans to improve or construct an addition to its laboratory at 27-01 Bridge Plaza, Long Island City, N. Y. Estimated cost will exceed $75,000.

Paint Factory—General Paint Corp., 1406 Dearborn St., Seattle, Wash., plans to rebuild its plant recently destroyed by fire with a loss of $110,000.

Paper Mill—P. A. Sorg Paper Co., 901 Manchester Ave., Middletown, O., plans to construct a 2 story factory and power plant at 1730 Grand Ave., Middletown. Estimated cost $40,000 or more.

Sulphite Pulp Mill—Port Royal Pulp & Paper Co., Ltd., Fairville, N. B., Can., plans to construct an addition to its mill and purchase additional equipment. $75,000.

Rayon Mill—Industrial Rayon Corp., H. Ritz, pres., West 98th St. and Walford Ave., Cleveland, O., contemplates extending its mill here. G. S. Rider Co., Marshall Bldg., Cleveland, archt. and engr. Estimated cost $2,000,000.

Tetra-ethyl Plant — E. I. du Pont de Nemours & Co., Wilmington Del., plans to construct a plant at Baton Rouge, La., for the manufacture of tetra-ethyl lead, a component of certain types of gasoline. Estimated cost $2,800,000.

Refinery—Lion Oil Refining Co., El Dorado, Ark., plans to improve and recondition its refinery at Smackover, Ark. Estimated cost will exceed $40,000.

Refinery—Tidewater Oil Co., 17 Battery Pl., New York, N. Y., will soon award the contract for the construction of a propane-butane rectification plant at Bayonne, N. J., to have a daily capacity of 45,000 gal. propane and 7,500 gal. butane.

Refinery—Waggoner Refining Co., Electra, Tex., plans to modernize its refinery. Estimated cost $100,000.

Roofing Factory—Toronto Asphalt Roofing Co., Ltd., Oxford Dr., Mt. Dennis, Toronto, Ont., Can., plans to construct a 1 story, 110 x 126 ft. addition to its factory. H. J. Smith, 62 Charles St., W., Toronto, archt. Estimated cost $40,000.

CONTRACTS AWARDED

Ammonia Compressor Plant—Mathieson Alkali Works, Inc., 2400 Buffalo Ave., Niagara Falls, N. Y., has awarded the contract for the construction of an ammonia compressor plant to Wright & Kremers, Inc., Pine Ave. and Main St., Niagara Falls.

Annealing Building—American Rolling Mill Co., Middletown, O., has awarded the contract for an addition to its box annealing building to F. H. McGraw & Co., 51 East 42d St., New York, N. Y. Estimated cost $60,000.

Distillery—Tom Bixler Distillery Co., Frankfort, Ky., plans to improve its distillery. Work will be done by separate contracts. Estimated cost will exceed $40,000.

Distillery—Tom Moore Distillery Co., Bardstown, Ky., plans to improve its distillery. Work will be done by separate contracts. Estimated cost will exceed $40,000.

Factory—Enamel Products Co., 341 Eddy Rd., Cleveland, O., has awarded the contract for a factory and boiler house to Austin Co., 16112 Euclid Ave., Cleveland. Estimated cost $40,000.

Factory—General Fireproofing Co., Youngstown, O., has awarded the contract for a 3 story addition to its factory to Heller-Murray Co., Youngstown. Estimated cost $100,000.

Factory—General Porcelain Enameling Co., 4101 West Parker Ave., Chicago, Ill., has awarded the contract for the construction of a factory to J. T. Carp, 2631 West Estes Ave., Chicago. Estimated cost $65,000.

Factory—Glass Containers, Inc., 3601 Santa Fe Ave., Vernon, Calif., will construct a 100 x 220 ft. addition to its factory. Work will be done by separate contracts. Estimated cost will exceed $37,500.

Factory—Gypsum Lime & Alabastine Canada, Ltd., Caledonia, Ont., Can., plans improvements to its plant. Work will be done by separate contracts and day labor. $40,000.

Rayon Mill—Tubize Chatillon Corp., 2 Park Ave., New York, N. Y., has awarded the contract for improvements to its mill at Rome, Ga., to Robert & Co., Bona Allen Bldg., Atlanta, Ga. Estimated cost $2,800,000.

Gasoline Absorption Plant — Panhandle Eastern Pipe Line Co., 61 Bway, New York, N. Y., has awarded the contract for the construction of a gasoline absorption plant at Liberal, Kan., to Stearns-Rogers Mfg. Co., 1720 California St., Denver, Colo. Estimated cost will exceed $75,000.

Gasoline Plant—Coltex Corp., Rodessa, La., has awarded the contract for a gasoline plant to Mattison-Wallack Co., Key Bldg., Oklahoma City, Okla. Estimated cost $40,000.

Gypsum Factory—U. S. Gypsum Co., 300 West Adams St., Chicago, Ill., has awarded the contract for a 1 story addition to its factory to Sill Construction Co., 520 North Michigan Ave., Chicago.

Paper Factory—Rogers Paper Co., Goodyear, Conn., has awarded the contract for an addition to its factory to Fred T. Ley & Co., Inc., 1215 Main St., Springfield, Mass. Estimated cost $47,000.

Wall Paper Factory—Stauntons, Ltd., 944 Yonge St., Toronto, Ont., Can., has awarded the contract for the construction of a wall paper factory to Carter-Halls-Aldinger, Ltd., 419 Cherry St., Toronto. Estimated cost $100,000.

Potash Development — Union Potash & Chemical Co., Avalon, N. M., plans potash development here. Separate contracts have been awarded for sinking shaft. Project will include mill and refining works.

Refinery—Radio Refining Co., McAllen, Tex., has awarded the contract for the construction of an oil refinery to R. W. Briggs Construction Co., Pharr, Tex. Estimated cost $60,000.

Rubber Factory—B. F. Goodrich Co., 1144 East Market St., Akron, O., has awarded contract for reconditioning rubber reclaiming plant for manufacture of auto tires at Oaks, Pa., to Robert E. Lamb & Co., Philadelphia, Pa.

Sugar Mill—Evan-Hall Sugar Cooperative, Donaldsonville, La., plans improvements to its sugar mill. Work will be done by separate contracts and day labor. Estimated cost including equipment $37,000.

Sugar Mill—Helvetia Sugar Mill, Central, La., plans improvements to its sugar mill. Work will be done by separate contracts and day labor. Estimated cost including equipment will exceed $40,000.

Sugar Mill—Waterford Sugar Mill, Killona, La., plans improvements and addition to its mill. Work will be done by day labor and separate contracts. Estimated cost including equipment $37,000.

Rack Warehouses—Hiram Walker & Sons, Inc., Peoria, Ill., has awarded the contract for the construction of two rack warehouses to Gamble Construction Co., 620 Chestnut St., St. Louis, Mo. Estimated cost $900,000.

GAIN IN PRODUCTION OF DIRECT DYES LAST YEAR

DOMESTIC production of coal-tar dyes in 1935 was the largest since 1929, the total reaching 101,932,661 lb. compared with an output of 87,177,612 lb. in 1934. Dye production in 1934 fell below that for the preceding year principally because consumers stocked up heavily in 1933 in anticipation of higher prices.

The 1935 output represents an increase over 1934 of slightly less than 17 per cent. In reporting production by classes of application, the Tariff Commission figures show that vat dyes continue to hold first place from a quantity standpoint even though indigo dyes are on a declining trend. Direct dyes which hold the second ranking place are gaining in favor and now account for considerably more than one-fourth of total production. The amount of direct dyes turned out last year was reported at 28,036,715 lb. including acetate silk dyes. This compares with 22,450,350 lb. for 1934 or a gain of more than 24 per cent. Hence the gain in production of direct dyes last year was at a rate considerably higher than that for total dye production. In fact an examination of dye statistics for recent years reveals that the percentage which direct dyes production bears to total production has been steadily gaining. For instance in 1929, direct dyes, accounted for 19.41 per cent of domestic production whereas in 1935 the figure had climbed to 27.5 per cent with the inclusion of the 1.93 per cent which was credited to acetate silk dyes.

Acid dyes also are moving upward as is shown by the fact that in 1932 they represented 11.71 per cent of total production and, gaining steadily through the intervening years, represented 14.32 per cent of total production in 1935. Sulphur dyes made a relatively good showing last year with 16.63 per cent of all production as compared with 15.42 per cent in 1934. The trend, however, has been away from sulphur dyes in recent years as may be seen from the standing of 21.32 per cent which that classification held in 1932. The sharpest decline is noted in the case of indigo. In 1929 this dye reached a tonnage higher than the total for any of the other classifications and was credited with 26.31 per cent of the year's output. With the exception of 1933, its progress since then has been along a descending line and last year it dropped to 13.36 per cent of the total.

Sales of dyes last year reached a total of 97,954,464 lb. compared with 87,177,612 lb. for 1935. While the increase in quantity was not far from 11,000,000 lb. it works out at only a little more than a 12 per cent for the year as against a rise of nearly 17 per cent in production. With only a slight change in imports and a gain of nearly 1,700,000 lb. in exports, domestic consumption of dyes last year appears to have approximated 83,000,000 lb., this total being reached by adding imports to the sales figure as reported and then deducting exports. On the same basis of calculation consumption in 1934 works out at around 70,600,000 lb.

Vat dyes including held onto first place in the sales total by a margin smaller than it had in the production end. Its rating was 27.38 per cent of total sales—a big drop from the 31.84 per cent for 1934 and 32.62 per cent for 1933. Direct dyes rated second in importance with a percentage of 27.12 including the 1.51 per cent reported for acetate silk dyes. Sulphur dyes which for the 1925-1930 period averaged 21.48 per cent of all dye sales was down to 17.36 per cent in 1935, its sales making a better showing than its production both on a percentage basis of total sales and of actual quantities involved, in other words sales of sulphur dyes last year were larger than the amount produced. Acid dyes with sales amounting to 14.46 per cent of the grand total continued the upward trend which has been reported for some time.

For the first time, vat dyes gave way in importance last year on a value basis, the leadership having been assumed by direct dyes with a per cent of 25.54 of the total for all dyes sold—29.19 per cent if acetate silk dyes are included. Then came vat dyes with 23.83 per cent, acid dyes with 21.51 per cent, and other classifications ranging down to 2.48 per cent for lake and spirit-soluble and 1.27 per cent for unclassified.

Production and Sales of Dyes

	Production Lb.	Sales Lb.
1935	101,932,661	97,954,464
1934	87,177,612	84,309,045
1933	100,952,778	98,238,398
1932	71,269,000	73,501,000
1931	83,526,000	85,220,000
1930	86,480,000	89,971,599
1929	111,421,505	106,070,887
1928	96,625,451	93,302,708
1927	95,167,905	98,339,204
1926	87,978,624	86,255,836

Foreign Trade in Dyes

	Imports Lb.	Exports Lb.
1935	4,606,270	19,630,924
1934	4,240,798	17,942,203
1933	4,288,214	18,740,356
1932	3,903,236	16,096,824
1931	4,944,141	20,312,768
1930	4,951,964	28,267,340
1929	6,437,147	34,130,325
1928	5,351,951	27,824,264
1927	4,233,046	26,770,560
1926	4,673,196	25,811,941

Production and Sales of Dyes by Classes of Application, 1935

Class of Application	Production		Sales			
	Quantity Pounds	Percent of total	Quantity Pounds	Percent of total	Value	Percent of total
Acid	14,593,749	14.32	14,168,009	14.46	$11,077,102	21.51
Basic	5,389,058	5.29	4,974,882	5.08	4,338,892	8.43
Direct	26,073,439	25.57	25,087,369	25.61	13,147,875	25.54
Acetate silk	†1,963,276	1.93	†1,479,600	1.51	†1,879,736	3.65
Lake and spirit-soluble	2,081,012	2.04	2,063,120	2.11	1,277,092	2.48
Mordant and chrome	6,264,133	6.14	6,308,849	6.44	3,041,479	5.91
Sulphur	16,949,143	16.63	17,009,957	17.36	3,798,351	7.38
Vats (including indigo)	27,908,296	27.38	26,180,465	26.73	12,272,209	23.83
(a) Indigo	13,614,238	13.36	14,051,451	14.35	2,452,243	4.76
(b) Other vats	14,294,058	14.02	12,129,014	12.38	9,819,966	19.07
Unclassified	710,555	.70	682,213	.70	655,625	1.27
Total	101,932,661	100.00	97,954,464	100.00	$51,488,361	100.00

†Includes certain dyes not classed as acetate silk dyes in 1934.

Production of Dyes by Colors and Classes of Application, 1935

	Blacks	Blues	Browns	Greens	Oranges	Reds	Violets	Yellows	Total
Acid	3,385,096	2,613,233	475,566	656,246	1,790,774	2,644,261	671,276	2,033,377	x14,269,831
Basic	23,670	949,879	723,109	282,970	659,385	808,735	1,008,600	932,710	5,389,058
Direct	12,994,624	3,122,522	2,255,325	944,180	749,063	3,024,905	442,030	2,542,792	26,075,439
Acetate silk	649,127	367,568	6,983	....	174,862	220,214	98,653	239,658	a1,963,276
Lake and spirit-soluble	930,860	96,073	4,038	2,365	297,438	587,144	2,804	160,290	2,081,012
Mordant and chrome	3,760,872	184,313	858,472	119,150	35,612	664,405	17,035	624,274	6,264,133
Sulphur	12,067,262	1,620,154	1,997,171	217,857	29,661	789,704	....	227,334	16,949,143
Vat	602,819	22,063,302	1,646,796	799,488	700,822	494,062	383,698	1,217,509	27,908,296
Unclassified	....	....	....	....	....	....	....	....	710,555
Total	34,414,330	31,017,044	7,965,460	3,022,258	4,437,617	9,233,428	2,624,096	7,977,744	xa101,608,743

x Food dyes not included.
a Includes 206,211 pounds not classified by color.